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The Association of Wealth over the Life Course with Health and Disease in Adulthood: An Analysis of Six Birth Cohorts from Five Low- & Middle-Income Countries

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Abstract

The Association of Wealth over the Life Course with Health and Disease in Adulthood: An Analysis of Six Birth Cohorts from Five Low- & Middle-Income Countries
By Jithin Sam Varghese

Wealth has a multifactorial role in health over the life course. Most studies exploring the role of wealth and other domains of socioeconomic position (SEP) with health outcomes in low- and middle-income countries (LMICs) have been cross-sectional. The aims of this dissertation are to measure and describe the dynamics of wealth mobility over the life course, the association of wealth mobility with health, and the relative roles of subjective and objective measures of SEP in predicting health. This dissertation investigates these questions among nearly 15,000 individuals with 22 to 51 years of follow-up through the Consortium on Health-Orientated Research in Transitional Societies (COHORTS) collaboration – a consortium of six birth cohorts from five LMICs (Brazil, Guatemala, India, Philippines and South Africa). First, the temporally harmonized asset index, created from consistently collected assets and housing characteristics, shows that wealth increased over the life course in all cohorts. Second, maternal and own attained schooling predicted future relative wealth mobility as measured by conditional wealth in four cohorts (Brazil, Guatemala, Philippines and South Africa). In turn, relative wealth mobility over the life course was positively associated with intelligence, and mobility in the most recent period was associated with emotional wellbeing and psychological distress. Third, life stages when relative wealth mobility was associated with BMI varied between cohorts consistent with anticipated cohort effects of the obesity transition. Fourth, subjective social status, after adjusting for objective measures of SEP (such as schooling, wealth and employment), showed small and consistent associations with happiness, but not BMI or psychological distress, in three birth cohorts (Guatemala, Philippines and South Africa). Based on the results of this research, recommendations for improving human capital in LMIC populations are proposed.

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List of Abbreviations

BMI: Body Mass Index

CLHNS: Cebu Longitudinal Health and Nutrition Survey

COHORTS: Consortium On Health Orientated Research in Transitioning Societies

EFA: Exploratory Factor Analysis

INCAP: Institute of Nutrition for Central America and Panama

LMIC: Low- and middle-income countries

MCA: Multiple Correspondence Analysis

NDBC: New Delhi Birth Cohort

PCA: Principal Component Analysis

PCR: Perceived Community Respect ladder

PES: Perceived Economic Status ladder

RPM: Ravens Progressive Matrices

SD: standard deviation

SEP: Socio-economic position

SHS: Subjective Happiness Scale

SRQ-20: World Health Organization's Self-Reporting Questionnaire-20

SSS: Subjective Social Status

WAIS-IV: Wechsler Adult Intelligence Scale-IV

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Chapter 1 Introduction

Have improvements in living standards, as measured by the construct of socio-economic position (SEP), resulting from economic growth, led to improvements in health and wellbeing? SEP consists of resource-based measures such as wealth, and prestige-based measures such as rank or status in a hierarchy (1). Longitudinal studies from high-income settings show how higher SEP on income, education or occupational class is associated with better health with SEP in childhood being more important than later life stages (2, 3). Since studies demonstrating the association of SEP with health outcomes in low- and middle-income countries relied primarily on cross-sectional surveys, we do not know if these findings generalize across contexts (4-8). Cross-sectional studies are prone to biases such as unmeasured confounding from early life characteristics, and unavailability of prospectively collected exposure information. Assessment of SEP is also prone to measurement error in these settings where individuals are not part of the formal labor market and are vulnerable to income shocks (9).

High wealth inequality during slow economic growth reduces social mobility, such that individuals persist in the same societal strata as their parents without an opportunity for advancement (10). Economic growth was slowing in most countries even before the SARS-CoV-2 pandemic. Quoting Amartya Sen, the Nobel prize winning economist, “relative deprivation in the space of incomes can yield absolute deprivation in the space of capabilities” (14). According to Sen, capabilities denote a person’s opportunities and their freedom to pursue them. The pandemic that began in 2020, disproportionately affected the socio-economically vulnerable in every country, with reversal of gains in poverty reduction, downward social mobility and rise in food insecurity. Projections suggest that economic recovery in most LMICs would not be sufficient to return to pre-pandemic per-capita income levels by 2022 (for two-thirds of emerging markets) and aggregate output would remain at 5.5% below pre-pandemic forecast in 2024 (11, 12). As economic growth slowly recovers after major pandemic slowdowns, some trends such as rising wealth inequality have accelerated (13). Lack of social mobility from inadequate access to resources (material, human or social capital) may expose individuals to harmful environmental exposures over their life course with adverse health consequences and fewer ways to ameliorate the burden (15, 16). The health implications of low or downward social mobility at different stages of life are understudied in LMIC settings primarily due to absence of life course data on SEP over time.

Wealth is a robust measure of SEP in societies that are vulnerable to uncertainties in income and employment (17). Asset-based indices, comprising of assets, housing characteristics and often public utilities, are useful proxies of wealth due to their ease of data collection and correlation with household expenditure on non-food items. Due to their nature of construction, they are relative measures within a community that cannot quantify wealth in the absolute sense. Asset indices were used previously to study changes over time in population-level wealth and inequality in its distribution (18, 19). A potential application of asset indices is to study change in relative rankings over time, i.e. wealth mobility – a component of social mobility, in LMICs. As such, major questions remain:

1. What are the determinants of wealth mobility in low- and middle-income countries?
2. What are the consequences of wealth mobility for different health outcomes?
3. Does wealth mobility at different stages of life have similar impacts on a health outcome?
4. Does prestige matter beyond material resources (such as wealth) or human capital (such as employment and education) in low- and middle-income countries?

The Consortium on Health-Orientated Research in Transitional Societies (COHORTS) is a consortium of six long running birth cohorts from five low- and middle-income counties (20). The birth cohorts are from Brazil (Pelotas 1982 cohort, Pelotas 1993 cohort), Guatemala (INCAP Longitudinal Study), India (New Delhi Birth Cohort), Philippines (Cebu Longitudinal Health and Nutrition Survey) and South Africa (Birth to Twenty plus cohort). Using consistently collected data over the life course, one can explore some aspects of the fore mentioned questions using the below research aims.

Research Aim 1: To develop an asset index as a proxy for wealth over the life course for low- and middle-income country cohorts

Research Aim 2: To estimate the association of relative wealth mobility at different stages of life course with health in late adolescence and early adulthood

Research Aim 3: To estimate the association of perceived community respect and perceived economic status with health in adulthood

This dissertation begins with a review of literature on measurement of socio-economic position and its association with health behaviors and health outcomes in low- and middle-income countries (Chapter 2). This dissertation primarily reviews research from LMICs since these associations have been well characterized in high-income settings. Chapter 3 describes the datasets, assumptions and statistical methodology used while attempting to answer the research questions described later. Chapter 4 describes the methodology of creating a measure of wealth that is comparable over the life course for longitudinal studies, what we term ‘temporally harmonized asset indices’ (alternately temporally harmonized wealth). Chapter 5 describes the describes the assumptions underlying conditional wealth and the construct of relative wealth mobility it represents using an example dataset. Conditional wealth measures for four birth cohorts are described in Chapter 6. This chapter then reports the determinants of relative wealth mobility and its associations at different life stages (childhood, school-age, late adolescence and early adulthood) with body mass index, intelligence quotient, psychological distress and emotional wellbeing in adulthood. Chapter 7 describes the association of a prestige-based measure, MacArthur Ladders for Subjective Social Status, with body mass index, psychological distress and subjective happiness (21). The chapter then explores how these measures are associated with health outcomes beyond material and human capital. Finally, Chapter 8 summarizes the findings from this body of research, as well as its strengths, limitations and public health implications.

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Chapter 2 Background

This chapter of the dissertation provides an overview of the complex construct of socio-economic position (SEP) and previous attempts to disambiguate it from other constructs of social stratification such as social class and socio-economic status. The chapter then summarizes previously reported associations of social stratification with different aspects of health. The chapter discusses how the construct of subjective social status, a self-reported measure of prestige, may relate to other components of SEP and its association with health. The chapter concludes by describing trends in social stratification over time and why the life course perspective is essential to designing public health interventions. The focus is to provide an overview of the relationship between SEP and health for LMICs and thus, omits research from high-income settings.

Disambiguating measures of social stratification

Many researchers from sociology and social epidemiology have disambiguated the different measures of social stratification – social class, socio-economic status and socio-economic position from each other to varying degrees (1-5). The researchers cited (Oakes, Galobardes, Howe, Krieger, Glymour et.al.) and many others dealt with complex issues involving SEP such as questions of measurement (identifying components, applicability to non-labor force populations, geographic heterogeneity) and mutability (does it change over time? if yes, under what conditions?). However, there is unanimous agreement with Link and Phelan that social stratification (or ‘socio-economic status’ as they described it) is a “fundamental cause of health inequalities” (6).

The construct of 'social class' is derived from Karl Marx and is associated with the structure of production resulting in differences in control of labor and resources between groups of individuals. Social stratification as defined by the three-component theory of Max Weber deals with distribution and exercise of power within a community. Weberian stratification deals with class (material resources and economic hierarchy), status (prestige and social hierarchy) and party (political influence). Howe remarks "most epidemiological measures of SEP have a Weberian focus, since they relate to individual rather than structural concepts" (1).

Krieger et. al. defines socio-economic position as a construct comprising both resource-based measures and prestige-based measures (7). Glymour et. al. in their comprehensive text on Social Epidemiology refer to SEP as how groups or individuals compare amongst each other ('relative') (2). The authors comment on SEP and socio-economic status (SES) are often used interchangeably with the latter conceptualized as differences in possession of resources ('absolute') (2). Oakes and Rossi define SES as one's access to collectively desired resources, and consequently a function of material capital (wealth, income, expenditure), human capital (innate abilities, skills and training) and social capital (networks, status, power) (3, 4). Throughout this dissertation, the term socio-economic position (SEP) is used, consistent with Oakes and Kaufman's comment that "in practical terms, the distinction between 'status' and 'position' seems trivial" (4). The following literature review is structured under the classification suggested by Oakes and Rossi of SEP as a function of material, human and social capital domains. However, many operationalized measures of SEP such as income, wealth, education and employment often overlap between these domains. For example, although education is primarily associated with cognitive skills or training (human capital), it may also confer access to diverse or influential social networks (social capital), such as college alumni associations, which are otherwise exclusive.

Social gradients in health in low- and middle-income countries

Economic, epidemiological, nutrition and obesity transition

The epidemiological transition from undernutrition and infectious diseases (marked by maternal and child mortality as well as anthropometric growth faltering) to chronic diseases (from longer life spans and changing dietary and physical activity patterns) is well characterized by several researchers (8-11). The determinants of this transition include rising standards of living from economic development, changing food environments driven by access to westernized-diets of ultra-processed foods, shift in employment from manual to non-manual labor, improvements in healthcare service and delivery etc. Previous research on components of this transition – nutrition transition and obesity transition, predict the following sequence at the country or population level: high undernutrition (underweight and linear growth failure), a rise in body mass index (and associated cardiovascular diseases) among high SEP groups, a rise in body mass index in the rest of the population, and subsequent decline in population prevalence driven by high SEP groups (12-16). The last stage hasn't been observed yet in LMICs (17-20).

Material capital and health

Consistent with Oakes and Rossi, the following operationalized measures in material capital are included for low- and middle-income countries: income, wealth (including inheritances) and expenditure. The International Labour Organization differentiates the material capital indicators into measures of capacity for consumption (income, assets, access to credit) and actual consumption (consumption expenditure) (21). Income (usually cash income), although easy to measure, may fluctuate in LMIC settings with high rates of informal employment. Income is also defined at the population-level by econometricians as the per capita value (output) generated by a geographic region or community. The World Bank in its country classification scheme uses Gross National Income per capita – a measure of domestic and foreign value claimed by residents of a country or region (22). Wealth in LMICs consist of land or house ownership, possession of assets, savings and capital investments. Wealth is a long-run measure of material capital in societies that are vulnerable to income volatility (23). Wealth is often operationalized through asset-based indices in community surveys. Despite their many limitations, asset-based indices are a reliable marker of relative wealth where substantial proportion of individuals still lack access to basic goods and services (24). Consumption expenditure, in the absence of individual (catastrophic expenditures or family events) and systemic shocks (such as COVID-19), is relatively stable over time as a measure of standard of living since households base their spending on anticipated income (21). This makes it a useful SEP measure for programmatic targeting. However, it is more difficult to measure (lengthy questionnaires on durable and non-durable items, measurement error from recall bias, prices for home produce, seasonality), compared to asset ownership (25). Asset-based indices are shown to be correlated with non-food expenditures in LMICs (26).Poirier et. al. provides a comprehensive review of literature that compares health and social inequities as measured by asset indices to that measured by income and consumption expenditure. They conclude that social stratification as measured by any of these indicators (asset indices, reported income, consumer expenditure) generally point in a consistent direction, although there are some contradictory results (24). Studies exploring the gradient of health across levels of wealth, as measured by asset indices, are consistent with the nutrition and obesity transition frameworks.

Interventions targeting material capital such as cash transfers, subsidies (food or agricultural) and access to credit via microfinancing have shown mixed benefits among beneficiaries (27-30). However, in line with addressing Sustainable Development Goal No 1 to "end extreme poverty in all its manifestations", many countries have implemented social safety net/social assistance (SSN/SA) programs. Of the 142 countries reviewed in a recent report, almost 70% countries have unconditional cash transfers, and 43% have conditional cash transfers, with other programs like school feeding or public works present in a majority of countries (31). Although spending on these is low (under 1% of GDP) for most LMICs, this has translated to almost 36% of people escaping absolute poverty and 45% reduction in poverty gap (distance between poverty line and average income for poor). However, the report also notes that only countries with substantial coverage, especially among the very poor, can make gains in poverty alleviation. Conditional and unconditional cash transfers in relation to human capital and health are discussed in the next section.

Among 115 studies from LMICs that were part of a systematic review, most reported an association between poverty and common mental disorders with consistent associations by levels of SES (conceptualized as an aggregate of education, income and residence) and housing but inconclusively for income (32). Another systematic review of 26 studies (8 were from LMICs), with substantial heterogeneity by age and geography, reported higher income inequality was associated with depression (33). Results from a randomized study in USA showed no association with a matched savings program assignment on depression after 10 years, but showed a negative association with current savings (34). Studies of cash transfer and microfinance interventions that aimed to alleviate poverty have shown null or mixed findings with improving mental health. Maselko hypothesizes that the economic boost from such interventions may not be sufficient given the high levels of poverty (35). Prince et.al. report from a systematic review of predominantly high income country studies that mental disorders predict onset of chronic diseases such as hypertension, diabetes and mortality from cardiovascular diseases, and treatment for maternal depression may lower stunting and improve child cognitive development (36). Additionally, the review reported that mental disorders are associated with increased alcohol and substance usage. Allen et.al. report that low SEP individuals in low- and middle-income countries are more likely to use alcohol and tobacco (37). Mendenhall et.al. report how with an increase in cardiovascular risk in low income populations in LMICs, we may soon observe a syndemic of diabetes, depression and infectious diseases (such as HIV or tuberculosis) driven by poverty (38). Together, this evidence suggests a pathway from life course SEP to onset of mental illness, that may make an individual susceptible to harmful lifestyles and subsequent chronic illness.

Studies by Kahneman and Deaton, as well as Killingsworth, based on data from the United States, have attempted to identify income levels beyond which income is not associated with evaluative wellbeing (life satisfaction) and experienced wellbeing (emotional wellbeing; comprising positive affect such as happiness and negative affect such as fear or shame) (39, 40). Both studies show a consistent positive association of income with evaluative wellbeing, with the Killingsworth study reporting no plateauing in the association with experienced wellbeing over income levels (39, 40). These results are consistent with studies from Central & Eastern Europe, Uganda, Guyana and Indonesia that report a positive association of income or wealth with subjective wellbeing and life satisfaction (41-44). The Study on Global Ageing and Adult Health in six LMICs (China, Ghana, India, Mexico, Russia and South Africa) also showed higher cross-sectional wealth was associated with happiness (45).

Human capital and health

Human capital consists of innate abilities (genetic or fixed endowments) and acquired skills, knowledge and education. Innate characteristics include the genetic component of intelligence (often conceptualized as fluid intelligence), and susceptibility towards cardiovascular and mental illness. Acquired human capital is an amenable mechanism to intervene on SEP when it is identified as a cause of health and disease.

Observational studies, including longitudinal studies, reporting positive associations between schooling and intelligence have limitations of unmeasured confounding and reverse causality (self-selection into higher schooling) (46). Evidence from natural experiments, such as mandatory schooling policies, which have led to higher attained schooling, showed improvements in IQ (47). For example, increasing the years of compulsory schooling from 7 to 9 years in Norway, show that a 1 year increase in schooling is associated with 3.7 point increase in IQ (48). A review of conditional cash transfers, mostly from Latin America, targeting school enrollment have led to higher attained schooling with mixed evidence of benefit for learning outcomes and labor market participation. However, the authors remark that these mixed results may be due to lower duration of follow-up and unobserved market forces in LMICs (30). These results were consistent with a review of cash transfers (conditional and unconditional) from Sub-Saharan Africa that demonstrated higher attained schooling but no differences in learning outcomes, higher food security, lower child labor, and higher social cohesion among other benefits (49). Schooling is correlated with better jobs and higher material capital. However, studies in LMICs demonstrate independent health gradients for schooling such that higher schooling is in general associated with better mental health and higher weight status, even after adjusting for asset-based wealth and employment status.

Results from Latin America and Africa suggest that heterogeneous associations of schooling with BMI by sex such that higher schooling is associated with lower obesity in women, but with higher obesity in men (50-52). The negative association of schooling with BMI in women was also observed in India when years of schooling is entered as a continuous variable as shown by Siddiqui et.al. and not as ordinal categories (as provided directly by DHS surveys), such that probability of overweight/obesity decreased beyond high school completion (53-56). The additional interventions that may result in improved weight status through higher fruit and vegetable intake or higher physical activity include imparting information, education or other cognitive factors particular to the desired behavior (57). However, these interventions although often report success to some degree, are criticized for not being cost effective (57).

A previously described systematic review reported that 11 out of 12 high quality studies showed low schooling was associated with higher common mental disorders, with 67% of 53 community-based studies reporting the same (32). The Study on Global Ageing and Adult Health in six LMICs and other LMIC studies, that reported positive associations with wealth, also showed higher schooling was associated with happiness (41-45). Beyond disparities in attained schooling due to gradients in early life SEP, consequences of interruptions (such as due to COVID-19) in schooling may include lack of access to nutritional supplementation or vaccination and early marriage (58).

Social capital and health

Social capital consists of ability to secure resources and advantages by virtue of membership in social networks and other social structures, and from utilization of relationships that the social structure provides (3). The schools of thought regarding the definition of social capital are divided into Putnam and Bourdieu. The former conceives social capital as features of a social organization, while the latter conceives it as the resources available to individuals as a result of their membership (59). The concept is different from the broader term of social cohesion that consists of absence of latent conflict as well as presence of social bonds (2). Moore and Kawachi suggest that social capital may be viewed as an ecological trait with individual-level health consequences (60). Villalonga-Olives and Kawachi suggest that individual and collective levels of analysis of social capital is required for a comprehensive perspective (61). Oakes and Rossi suggest that it may also be viewed as an individual, family or household-level trait (3).

Broadly, social capital is divided into cognitive (quality of interactions) and structural (quantity of interactions) components, with differences at individual and ecological levels (62). Cognitive social capital consists of values and norms within a community, and is measured using domains such as trust, social cohesion, social support, and sense of community. Structural social capital consists of formal organizations that link individuals together, and are measured using membership in groups, engagement in public affairs and community networks (60). Research on social capital has gained substantive importance in the last two decades. A recent review of association of social capital showed that an individual's cognitive capital was negatively associated with common mental disorders, while an individual's structural capital showed mixed associations potentially due to its culture-specific nature (62).

Subjective social status and health

Subjective social status is one's perception relative to others in their community (or another frame of reference) with regards to measures such as occupational prestige, level of education and wealth (63, 64). SSS is typically measured using rungs of a ladder scale (MacArthur ladder) that asks one to rate themselves relative to others on a scale of 1 to 10 (highest). One’s perception of prestige may not be entirely predicated on objectively measured components of SEP, and may be influenced by age, race-ethnicity, sex and socio-cultural norms (65-67). Additionally, different components of objective SEP may have varying utility in predicting SSS scores across contexts (68). Previous studies of association of SSS with health outcomes display positive associations with better health after adjusting for objective measures of SEP (69). Subjective social status is discussed in detail in Chapter 7.

Importance of life course perspective on health

A life course perspective on health and wellbeing allows us to identify sensitive periods that are amenable to intervention. Distinguishing the former from critical periods (i.e., periods at which an exposure may have irreversible consequences), a sensitive period represents a phase of life during which the exposure is associated with increased risk but there is scope to modify or reverse those changes outside the time window (70). Social gradients in health and disease may therefore be due to socially-patterned exposures at different stages of the life course, as remarked by Davey Smith et.al on mortality (71).

Age-period-cohort effects in life course epidemiology

Simultaneous identification of Age, Period and (birth) Cohort effects are not possible from a single cohort since the third component is linearly dependent on the other two (i.e., Period = Cohort + Age) (72). Different birth cohorts even within the same broader context (say country or community) may experience different life course exposures and subsequently, different risk of disease in adulthood. Cohort effects are the association of a set of exogenous contextual exposures experienced by the cohort with disease status later in life. Age effects are the association of age-related intrinsic changes (physiological and socio-cultural norms such as marriage or child bearing) with disease status that are consistent between cohorts. Period effects are the association of period exposures (exposure to a pandemic or recession) with disease-status, that are applicable to all cohorts. The identification of these separate effects, which may have multi-level interactions, provides an opportunity to attribute causality to underlying socio-environmental factors (cohort effects) beyond immutable biological or socio-cultural traits (age effects) (70, 73). A visual representation of age-period-cohort effects is provided in **Fig 1**. Furthermore, initial social disparities in health in early life may diverge (accumulation of risk) or converge (age-as-leveler process) over time, requiring cohort studies as opposed to cross-sectional surveys to avoid confounding age-cohort effects (73).

Life course epidemiology of body mass index

Nutrition transition studies exploring SEP gradients for weight status provide only a cross-sectional perspective and doesn’t identify key life stages associated with development for overweight and obesity. A study from the United States using National Health and Nutrition Examination Survey-I (NHANES-I) Epidemiologic Follow-up Study, among participants born between 1897 and 1946, reported childhood overweight was a predictor of adult severe obesity, with stronger association in men (74). However, women had higher prevalence of severe obesity and were more likely to manifest it long term. A third of participants with severe obesity in adulthood were overweight in childhood (74). Life course epidemiologists have posited both early life factors (during pre-pregnancy, pregnancy, early childhood) and adult characteristics are important at the individual level for obesity, apart from macro-level environmental determinants (75, 76). Life course tracking of overweight and obesity is associated with higher cardiovascular risk in adulthood (77).

The identification of underlying drivers of overweight and obesity becomes more complicated when comparing populations across high-income countries and LMICs, such as the nutrition or obesity transition studies that rely on cross-sectional data, relative to an aggregate measure (such as per capita gross national income or income inequality) (78, 79). Such studies may inadequately describe the complex phenomenon of country-age-period-cohort effects of trends in social disparities by levels of economic development (13, 80-82). For example, under the same level of economic development and assumptions of no country-level heterogeneity, the prevalence of overweight and obesity may be higher among the rich in older cohorts and higher among the poor in younger cohorts. This suggests that a cohort effect that is conflated with age may be masked when assessing pooled period prevalence of overweight and obesity. The consequence of this pooled inference, as opposed to age-stratum specific inference would be broader, untargeted interventions as opposed to more targeted ones. Additionally, given the slowing economic growth pre-pandemic, rising wealth inequality and local economic downturns experienced by many LMIC economies, it is unknown how social disparities in disease prevalence change over time and between birth cohorts.

The assumptions for the obesity transition when re-stated in age-period-cohort terms and under sustained economic growth as has been observed post-World War II for most countries may be as follows (13):

1. Older cohorts have high prevalence among rich relative to poor, and in women relative to men

2. Younger cohorts have high prevalence among rich and poor, with smaller disparities relative to older cohorts

3. Youngest cohorts have slightly higher prevalence among poor relative to rich

4. National and sub-national level effect modifiers such as globalization and urbanization may accelerate or decelerate this process (83).

Analysis of one birth cohort study does not allow identification of age effects since the results may be specific to that cohort (cohort effects). Using multiple, staggered birth cohort studies with overlapping age ranges allows identifying both secular (cohort effects) and age-related (age effects) trends. An example when age and cohort effects were estimated separately is an analysis of four US-based cohorts (Add Health, MIDUS, ACL and HRS; ages 11 to 90+ y) with overlapping age-ranges that suggested socio-economic disparities in BMI in childhood and adolescence, followed by a peak in disparities in young and middle adulthood and a convergence in BMI in late adulthood (73). Additionally, successive cohorts displayed higher average BMI and rate of increase in BMI by age, relative to previous cohorts. The pooled analysis by Yang et.al. modeled age trajectories to study cohort effects (inter-cohort and intra-cohort). The challenge is separating out period effects from age and cohort effects. Yang et.al. eliminated concerns regarding period effects using two alternatives. Period effects, according to the authors, could be conceptualized as an interaction of age and cohort. First, age-by-cohort interactions, if significant, could detect period effects. Second, given that the different cohorts included span different periods, birth cohort-by-study interactions if significant, would indicate period interactions at different calendar time periods (73). However, Bell and Jones interpret the age-by-cohort interaction as differences in life course effect trajectories across cohorts, and not as period effects (84). The authors suggest that the model with age-by-cohort interactions assume period effects as absent.

Life course epidemiology of intelligence

Historic studies of general intelligence by Spearman maintained that the construct is a single quantitative factor that is innate and not malleable, i.e., not determined by external influences (85). This was subsequently disproven as early life cognition is only partially predictive of future intelligence (46) and advantages gained from high quality pre-school education or better early life environments are lost if quality of education in later years is poor (86-88). Later studies by Thurstone showed that Spearman's one-factor model is too simplistic and arrived at multiple statistically independent cognitive abilities such as word fluency and perceptual speed with each ability measured by a number of tests. Research on 'investment theory' by Cattell suggested higher order intelligences driven by an underlying reasoning capacity (fluid intelligence) and acquired cognitive abilities (crystallized intelligence). Variance in the former is hypothesized to be due to genetic makeup while variance in the latter is a function of gene-environment interactions (85). Carroll posited a third factor in addition to fluid and crystallized intelligence, named 'general factor', which represents differences in cognition beyond the former two factors. The mutualism model of general intelligence posits that heritable resources constrain cognitive development and different cognitive abilities influence each other beneficially (89). Additionally, Kan et.al. suggest group (e.g. racial or ethnic) differences in intelligences may display high heritability due to shared environments, and not just shared genetics, with high cultural heritability in crystallized intelligence, contrary to the investment theory (85). Intelligence is therefore attributed to a combination of genetics and environment, with substantial gene-environment interactions. The share of heredity increases in adulthood (90). This evidence comes mainly from high-income country studies of monozygotic and dizygotic twins raised in the same household and raised apart (90, 91). Life course socio-economic position is associated with early life cognition (and vice versa), attained schooling, adult intelligence and later-life cognitive decline (91-93). High childhood IQ, consequently, is associated with social mobility (94).

The Flynn effect implies a cohort effect for IQ such that successive cohorts have higher IQs than the previous cohorts (decadal growth of nearly 3 points) due to either early life environments (and higher potential at birth) or due to greater cognitive demand from a more cognitively challenging world (95). Lynn suggests that it may be due to better pre-natal and early post-natal nutrition given that gains of 3.7 – 3.9 units were observed in pre-school children who were (96). However, Flynn suggested alternatively that these gains were potentially due to culture-driven cognitive priorities based on the evidence that most of the gains were in some domains (fluid intelligence, Similarities) and not others (vocabulary) (97).

Life course epidemiology of mental health

The link between low SEP and depression may be bidirectional, such that social causation (low SEP causes depression through relative deprivation or poverty) and social selection (depression causes poverty through stressful life experiences or income loss) may operate sequentially or at different life stages (98). Most studies of SEP and mental health suggest a role for social selection in early life, and social causation after adolescence (99, 100). However, studies also suggest that early life onset of mental disorders, predominantly before 15 years of age, is associated with parental SEP (101, 102). As previously noted in Prince et.al., psychological distress and mental illness may predict risk behaviors as well as communicable and non-communicable diseases (36). A call for increased funding to address mental health burdens may result in synergistic benefits for chronic disease treatment. Therefore, a comprehensive treatment plan ought to involve basic drug and psychotherapeutic interventions (such as culturally-adapted cognitive behavioral therapy) at all levels of health care, especially at the primary health care facilities, to improve adherence to life style behaviors and medications for preventing future illness (36, 38).

Growth, inequality and social mobility in LMICs

Poverty, growth and health

Economic growth is associated with epidemiological and nutrition transitions via unhealthy diets and sedentary lifestyles (12). An evaluation of the Opportunidades cash transfer program from Mexico showed lowered depression symptoms in the intervention group (35). Poverty alleviation is also associated with lower psychological distress (98). Cumulative low SEP as measured by occupational class and by income poverty was associated with mortality and daily living (functioning, depression) in cohorts from UK and USA respectively (103, 104). When there is limited upward social mobility that has been decreasing since the middle decades of the 20^{th} century in US and UK (105-108), one can rely on early life SEP as a proxy for adult SEP (109). However, in settings that have experienced changes in inequality or social mobility in indicators that are proximally associated with health, it is important to disambiguate their effects from that of economic growth or poverty alleviation.

Inequality and health

Income (or other SEP) inequality may operate through the mechanism of "relative deprivation" suggests Wilkinson et.al (110). Relative deprivation involves how the community or local area of residence stands in comparison to the rest of the society, and is important given that communities tend to cluster in terms of health and disease. According to Wilkinson, income inequality operates across the whole society as the main cause of societal differentiation (and relative deprivation), and thus results in health inequities. Wilkinson et.al. suggests greater redistribution of incomes via taxation, in addition to providing more material resources to address health inequities and psychosocial mechanisms (related to chronic stress from lack of control, low perceived status etc).

Marmot points out the social gradient in health outcomes existing in societies with differing levels of inequality (and egalitarianism) such as civil servants in the UK (Whitehall study), Oscar winners in USA and PhD graduates in Sweden (111-113). He attributes the lower health status for a low SEP individual to lack of control and inability to participate in society, such that relative position displays an association with health beyond one's income. This results in low grade chronic stress that activates one's endocrine (HPA axis) and neuroendocrine (epinephrine and norepinephrine) pathways. Marmot quotes Amartya Sen's work on the capabilities approach: "Relative deprivation in the space of incomes can yield absolute deprivation in the space of capabilities" (114). However, Marmot notes, that the health implication for one's relative position within a society varies and depends on the nature of the society.

Deaton comments that the association of 'relative income' with health may be driven by income inequality but does not imply the same, contrary to Wilkinson who labels it the "relative income hypothesis" (115). Deaton also comments that if rank (or position) were all that matters, then higher income (or SEP) for everyone should not have any effect on health.

Jones-Smith et.al. using data from repeated cross-sectional surveys (1989 to 2007) of 37 LMICs suggest that among countries with high GDP per capita, lower income inequality was associated with higher growth rate of overweight among low SEP, relative to higher SEP (116). Income inequality and mental health have mixed associations, as reported by Maselko, with studies in South Africa and Mexico showing null results, while a study from Brazil showed an association with depression (35). These mixed findings may be due to the limitations of Gini index as an indicator of inequality as well as differences in cultural interpretation of inequality.

Mackenbach comments on how persistence of health inequalities in modern European welfare states could be seen as a failure to implement more radical redistribution measures, resulting in low social mobility and high social persistence between successive generations (117). Similar results were reported by Neidhofer who suggests countries in Latin America with high income inequality may have low intergenerational social mobility (118). Using data from the World Value Survey, Garcia-Munoz et.al. remarks that income inequality is not associated with life satisfaction (subjective well-being) in LMICs provided there are opportunities for social mobility in the country (119).

Contrary to many of the above findings, Semyonov et.al. using nationally representative surveys from 16 countries suggest that income inequality does not modify the wealth-health gradient in high income countries and mean health improves with economic development (120).

Social mobility and health

Beller and Hout comment that slowing economic growth since 1975 and wealth inequality has led to lower intergenerational occupational social mobility and low income mobility in USA (121). They comment that growing inequality may not hamper social mobility, but increase the difference between the upwardly and downwardly mobile, requiring one to climb farther especially by those who are in the middle SEP groups. However, they also remark that higher inequality may lead to higher social persistence in low and high SEP groups. Song et.al. comment on how intergeneration mobility in USA increased for those born before 1900 and fell for those born after 1940 (106). These results are consistent with the findings of Chetty et.al.

who show intergenerational income persistence and higher income inequality for children born between 1971 and 1993, relative to their parents (122). Chetty et.al. also show how these trends may have geographic heterogeneity with counties that have less residential segregation, less income inequality, better primary schools, greater social capital and greater family stability associated with higher social mobility (123). McGue et.al., using data from the Minnesota Twin Family Study, showed how higher IQ in children (relative to their parents) and polygenic risk score from a Genome Wide Association Study (GWAS) were potentially associated with absolute educational mobility (attainment of higher educational level) and absolute occupational mobility relative to their parents (124). However, they also find high intergenerational social persistence in the study sample. Causa and Johansson, as well as Garbinti and Savignac echo these findings, with results from OECD countries suggesting high social persistence in most of South Europe, while Nordic countries offer the most social mobility as a result of progressive public policies in early childcare and education (125, 126). Using data on surnames and wealth inheritances, Clark et.al. show high intergenerational wealth elasticities (1858 – 2012; regression coefficient of child's log wealth on parental log wealth) in UK, similar to results from USA by Pfeffer et.al. (127, 128). Krzyzanowska and Mascie-Taylor comment on how attained schooling, mathematics score, reading and non-verbal IQ (only in boys) and parental social class were the best predictors of social mobility (equivalently social persistence) categories in UK between 1958 and 1991 (129).

Behrman remarks that intergenerational mobility in Latin America is less than USA (as per 2004 data), and social mobility in LMICs is driven by parental human capital and endowments and parents' investments in child's education (130, 131). These results are consistent with more recent data from Neidhofer et.al and Azevedo who show higher absolute ("structural") intergenerational educational mobility but low relative ("exchange") mobility (132-134). The Fair Progress report that studied intergenerational educational and income mobility in 148 countries in absolute (higher living standards) and relative (extent to which SEP is independent of parents' SEP) terms suggests substantial temporal and geographic variability (135). Both forms of mobility, according to the report, are important with absolute mobility is associated with net improvements in living standards and social cohesion, while relative mobility is associated with fairness. According to the report, relative educational mobility has declined and there is high intergenerational educational persistence in LMICs. Iverson et.al. comment on challenges in measuring mobility in LMICs (136). For example, using intergenerational regression coefficient (IGRC; regression coefficient of child's SEP on parental SEP) and intergenerational correlation coefficient (IGRC times the ratio of standard deviations between parent's and child's generations) may show different results such that IGRC suggested higher mobility, while IGC suggests social persistence (low mobility). Iversen et.al. also comment on how educational mobility has not translated into occupational mobility, and due to absence of longitudinal studies, there is insufficient information on the drivers of social mobility in LMICs (136).

The association of social mobility with health is governed by theories such as 'dissociative theory' (upward mobility is a stressful experience), 'falling from grace theory' (downward mobility is harmful) and 'acculturation theory' (health is a result of different social contexts with low stress in maneuvering class transitions) as per Jonsson et.al (137). Studies reporting associations of social persistence in high or low SEP groups, social mobility between these groups and health from LMICs are generally consistent with high income countries (USA, UK, Nordics) for different measures of SEP (138-144). Individuals who experience high SEP persistence over their life course have the best health. Individuals who experience upward mobility typically tend to have health statuses that are in between those who were always higher SEP and always lower SEP (145-147). Results from the Cuiaba cohort in Brazil also showed that belonging to persistently high SEP was associated with higher overweight and obesity in adolescence, similar to results of the Pelotas birth cohorts in childhood (148, 149). Results from the ELSA-Brasil cohort show no association of intergenerational upward mobility with CVD, although those who experienced downward mobility may have higher intima-media thickness (a marker of subclinical CVD) (150-152). However, many of the LMIC studies, including the ELSA-Brasil cohort, rely on self-reported measures of parental or early life SEP, with potential for reporting bias.

Summary

Socio-economic position is a fundamental cause of health disparities. Persistent high SEP over the life course is associated with higher intelligence, better mental health and wellbeing. Depending on the country and birth cohort, high SEP may have differential associations with BMI. When economic growth decreases and wealth inequality widens, social mobility may be low. This may have consequences for physical and mental health at the individual and community level.

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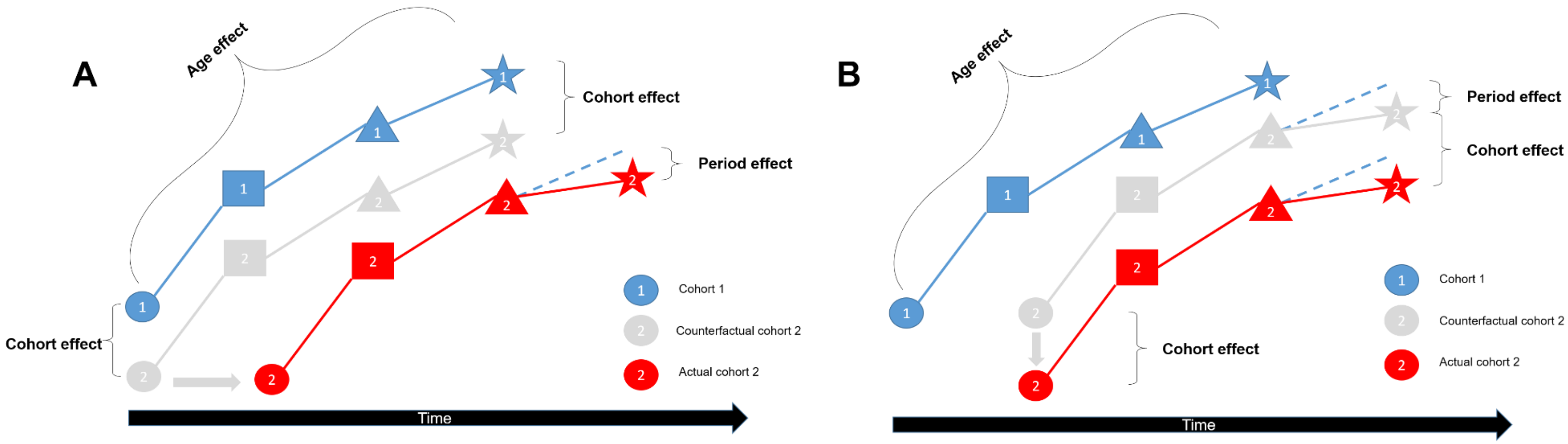
Figure 2.1 Age-period-cohort effect decomposition



Age-period-cohort effects are difficult to identify due to linear dependencies. Using multiple cohort studies from the same source population with overlapping age ranges may provide us with an estimate of these effects. The ‘age effect’ displayed assumes that age-related biological and socio-cultural exposures that are intrinsic to cohort 1 are equivalent to that experienced by cohort 2. Both panels (A & B) are equivalent. Panel A displays the conceptualization of a counterfactual cohort that is displaced by cohort effects. Panel B displays the conceptualization of a counterfactual cohort that is displaced by time and period effects. Given the disagreements in conceptualization of age-by-cohort effects as period effects, I choose to represent the period effects for cohort 2 alone.

Chapter 3 Overview of methods

This chapter provides a summary of the various data sources and statistical methods used to answer the proposed research aims. The chapter is divided into two parts: Data and Statistical Analysis.

Data

We used data from the Consortium on Health-Orientated Research in Transitioning Societies (COHORTS) – a consortium of six birth cohorts from five low- and middle-income countries (1). Previous research from the COHORTS collaboration have been instrumental in highlighting the importance of early life nutritional status, especially the first 1000 days, for adult health and human capital (2-18). We provide additional information on data collection instruments and procedures for wealth and health outcomes under the Methods section and supplementary material of the corresponding chapters.

Pelotas 1982 cohort

The Pelotas 1982 cohort consists of 5914 live born infants during the calendar year 1982 in the city of Pelotas, Brazil (19, 20). The cohort was followed-up periodically (last follow-up in 2012) and information on socio-economic and demographic characteristics, nutrition, psychosocial development and other variables were collected using a combination of interviewer-applied questionnaires and physical examination. The cohort did not collect data on assets and housing characteristics consistently, and is therefore omitted from our analysis for Aims 1 to 3.

Pelotas 1993 cohort

The Pelotas 1993 cohort, consisting of 5249 live born infants, was started with an original goal to comparatively assess trends (with Pelotas 1982 cohort) in maternal and child health indicators (21-23). Information on possession of assets and housing characteristics, i.e. wealth, were periodically collected at 3-4y, 11-12y, 13-14y, 18y and 22y. The last follow-up was in 2015, when the participants were 22 years old, during which time information on physical health, mental health and emotional wellbeing were collected, apart from wealth data. Data from the Pelotas 1993 cohort was used in Aim 1 and Aim 2.

INCAP Longitudinal Study

The INCAP Longitudinal Study consists of 2,392 participants born in four villages of El Progreso, Guatemala (24, 25). The study was originally designed as a cluster-randomized nutrition supplementation trial to study the effect of 'atole' – a high energy, high protein supplement, versus 'fresco' – a low energy supplement with similar levels of micronutrients from the period 1969 to 1977. Participants were followed up to the age of 7 years or from birth till study completion, with the oldest participant born in 1962 and the youngest born in 1977. Asset data was collected in 1967, 1975, 1987, 1996 and 2002 as part of village censuses for those who resided in study villages at the time of data collection. Asset data was collected in 2015-16 and 2017-18 for all participants. The follow-up in 2015-16 collected data on physical health, psychological distress and intelligence, apart from socio-demographic characteristics (26). The follow-up in 2017-18 collected data on MacArthur ladders for subjective social status, psychological distress, executive function and wellbeing, apart from other socio-emotional measures and socio-demographic characteristics (27, 28). Data from the INCAP Longitudinal Study was used in Aims 1 to 3.

New Delhi Birth Cohort

The New Delhi Birth Cohort (India) consists of 8181 singleton births to married women in 1969-72 (29). Participants were followed-up in adulthood at ages 27-33y (1998-2002), 34-40y (2006-09), 40-47y (2012-14) and 44-51y (2017-20). Data on assets and housing characteristics as well as physical health were collected at all adult waves. However, asset data was unavailable for study waves before 1998. Data from the New Delhi Birth Cohort was used for Aim 1.

Cebu Longitudinal Health and Nutrition Survey

The Cebu Longitudinal Health and Nutrition Survey (CLHNS) consisted of 3327 pregnant women from a single-stage cluster sample of urban and rural barangays in Metro Cebu (30). Among all pregnancies, 3080 singleton and 26 multiple births were followed-up during subsequent study waves in childhood, 7-8y (1991), 12-13y (1995), 15-16y (1998), 18-19y (2002), 21-22y (2005), 23-24y (2007), 25-26y (2009), and 33-36y (2017-18). Data on assets and housing characteristics were collected at all waves. Data on physical health, psychological distress, intelligence quotient, MacArthur ladders for subjective social status, and subjective happiness were collected in 2017-18. Data from the CLHNS cohort was used for Aims 1 to 3 and for Chapter 5 on conditional wealth.

Birth to Twenty plus study

The Birth to Twenty plus study consists of 3273 singleton births who were residents of Soweto, Johannesburg born during a seven-week period in 1990 (31). Data on assets and housing characteristics were collected at birth, 7-8y (1997-98), 12-13y (2002-03), 16-17y (2006-07), 22-23y (2012-13y) and 27-28y (2017-18). Data on physical health were collected in 2012-13. Data on psychological distress, intelligence, MacArthur ladders for subjective social status, and subjective happiness were collected in 2017-18. Data from the Birth to Twenty plus study were used for Aims 1 to 3.

Statistical Methods

Principal Components Analysis

Principal Components Analysis (PCA) is a statistical procedure that reduces p-dimensional data into a set of p orthogonal components, such that the first component explains the most variance (32). PCA is typically performed on datasets comprising of continuous variables that may be multivariate normal. If the data are multivariate normal, then the components are expected to be independent (33). If data are not multivariate normal, then there may be higher order dependencies between linearly independent components.

Multiple Imputation

Multiple imputation (MI) is a statistical procedure to impute missing data while retaining all available information and minimizing potential selection bias from complete-case analysis under a missing at random assumption (34). The MI procedure consists of three steps – imputation, analysis and pooling (34, 35). In the imputation step, the procedure generates ‘m’ datasets, where each missing value (value missing for any variable for any observation) is imputed with plausible values using parametric (e.g. multivariate normal model) or non-parametric (e.g. predictive mean matching or nearest neighbor) procedures. The analysis step consists of estimation of parameters of interest for each of the ‘m’ datasets, followed by a pooling procedure to combine the ‘m’ estimates into a single estimate. The pooling procedure incorporates uncertainty in imputation (variance in estimates between datasets) as well as the uncertainty in estimation (standard error of coefficients), and the resulting standard error would be wider than that from a single imputation (36).

Given the non-monotone nature of the cohort studies included in our analysis, we used multiple imputation with chained equations (MICE) procedures after restructuring the longitudinal data into a wide dataset and included auxiliary variables (variables included in imputation step but not in analysis step) whenever they were available. We used predictive mean matching, a procedure where observations with incomplete data are matched to similar observations (but with complete data), and missing values are drawn from a distribution of observed values among the matches (34).

Inverse Probability of Attrition Weighting

The Inverse Probability of Attrition Weighting (IPAW), or inverse probability weighting (IPW) in general, involves specifying a probability model for loss to follow-up in epidemiological studies to eliminate selection bias under a missing at random assumption. IPAW re-weights the observed data to generate estimates from a pseudo-population that includes potential outcomes of those who did not provide outcome data, requiring only a model for missingness of the outcome and not the full data (37, 38). This is different from Multiple Imputation which requires a model for distribution of missing data given the observed data for all variables (39). In the case of outcome data alone being missing, an IPW model that correctly models probability of missingness is less efficient (i.e, has higher standard error for estimates) than a correctly specified MI model (39). However, IPW has several advantages. Firstly, it is easier to understand. The model involves estimating the probability of missingness (i.e. Pr[Data Available| Covariates]) using a statistical model such as logistic regression, and incorporating the inverse of the predicted probability as weights in a complete-case analysis. Second, results from

MI may be biased if there is a substantial fraction of missing information. Third, MICE require pre-specification of interaction terms in the imputation step. This causes issues of model compatibility between the imputation model and the analytic model (35). Fourth, in the absence of auxiliary covariates for imputing the outcome, MI may lead to high standard errors for estimates (40, 41). Fifth, since MI assumes that the observed data is similar to the incomplete data, the standard errors produced during the analysis step may be biased downwards. If the predictors of missingness are different in missing and observed data, the low efficiency due to the highly variable inverse probability weights are justified and IPW reflects genuine uncertainty that MI doesn't capture (39).

Robust methods

Ordinary least squares (OLS), commonly known as linear regression gives the best linear unbiased estimates (BLUE) of associations under assumptions of linearity, homoskedasticity, independence of observations, independence of predictors and normality of residuals. When homoskedasticity and normality assumptions are violated due to outliers or high leverage (highly influential) points, robust regressions are a useful alternative (42, 43). Robust methods are also useful when independence of observations is violated due to spatial or temporal auto-correlations, such as is the case with longitudinal data (44). Robust standard errors are typically estimated using weights in an iterative fashion that determine the contribution of each residual to the objective function of the regression, similar to a weighted-least squares estimation. However, unlike WLS, since residuals are dependent on the coefficients and vice-versa, arriving at the optimal solution requires an iterative procedure (e.g. Iterative Reweighted Least Squares or IRLS) (43). Additional usage of robust standard errors is in estimation of risk ratios using

Poisson Regression for binary outcomes due to misspecification of the relationship between the mean and variance (45).

Marginal Linear Models

Marginal Linear Models and Linear Mixed Models are two of the modern approaches used to model autocorrelated, normally distributed outcome data clustered either in space (primary sampling units) or time (repeated observations on an individual or unit). Both approaches give similar estimates for exposure-outcome associations but are fit under different modeling frameworks. The former is fit using a generalized estimating equation (GEE) framework (quasi-likelihood estimation), while the latter uses maximum likelihood estimation. Although their estimates are similar, marginal models, as the name suggests, provide marginal estimates across all clusters, while mixed models provide conditional estimates (conditional on the cluster's random effects) (46, 47). Marginal models additionally allow misspecification of the correlation structure ('working correlation structure') between observations in a cluster by using robust standard errors. However, correct specification of the correlation structure can help in better estimation of standard errors. A weighted GEE approach could additionally allow us to combine data on missingness of outcome (under a missing at random assumption) using inverse probability weights for loss to follow-up (48).

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Chapter 4 Changes in asset-based wealth across the life course in birth cohorts from five low- and middle-income countries

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Data availability statement: The code for the analysis is available on https://github.com/jvargh7/cohorts-asset-harmonization. Data will be available upon reasonable request addressed to the principal investigators at each study site.

ABSTRACT

Background: Temporally-harmonized asset-based measures of wealth can be used to study the association of life-course wealth exposures in the same scale with health outcomes in low- and middle-income countries (LMICs). The within-individual longitudinal stability of asset-based indices of wealth in LMICs is poorly understood.

Methods: Using data from five birth cohorts from three continents, we developed temporally-harmonized asset indices over the life course through polychoric principal component analysis of a common set of assets collected consistently over time (18 years in Brazil to 50 years in Guatemala). For each cohort, we compared the harmonized index to cross-sectional indices created using more comprehensive asset measures using rank correlations. We evaluated the rank correlation of the harmonized index in early life and adulthood with maternal schooling and own attained schooling, respectively.

Results: Temporally-harmonized asset indices developed from a consistently-collected set of assets (range: 10 in South Africa to 30 in Philippines) suggested that mean wealth improved over time for all birth cohorts. Cross-sectional indices created separately for each study wave were correlated with the harmonized index for all cohorts (Brazil: r = 0.78 to 0.96; Guatemala: r = 0.81 to 0.95; India: 0.75 to 0.93; Philippines: r = 0.92 to 0.99; South Africa: r = 0.84 to 0.96). Maternal schooling (r = 0.15 to 0.56) and attained schooling (r = 0.23 to 0.53) were positively correlated with the harmonized asset index in childhood and adulthood respectively.

Conclusions: Temporally-harmonized asset indices displayed coherence with cross-sectional indices as well as construct validity with schooling.

KEYWORDS: wealth index, life course epidemiology, social mobility

KEY MESSAGES:

- Wealth, as measured by temporally-harmonized asset indices, could be used to assess relative importance of wealth gains on the same scale at different life stages with health in low- and middle-income countries.
- Temporally harmonized asset indices created from a restricted set of assets were correlated with cross-sectional asset indices created using all available assets in five LMIC birth cohorts.
- Harmonized indices displayed construct validity, as demonstrated by its correlation with schooling.
- Harmonized indices were robust to alternate specification of instruments such as shorter list of assets, study years, and factor extraction procedures.

Introduction

Low- and middle-income countries (LMIC) have experienced a rise in material living standards from investments in human capital and rise in global trade (1). This economic transition parallels demographic and epidemiological transitions wherein the burden of diseases has shifted from infectious diseases and maternal, child and newborn illnesses to non-communicable diseases (2-5). Previous research has reported that these transitions tend to percolate down from those belonging to high socio-economic position to low socio-economic position in LMICs (6).

Wealth, a dimension of material wellbeing, is an indicator of socio-economic position (SEP) in societies that are vulnerable to income shocks and unforeseen expenditures (7, 8). Asset indices are useful proxy measures of wealth in LMICs where ownership of household items, high-quality housing and public services are not universal (9). Asset indices are reflective of long-run cumulative economic status and are correlated with expenditures on non-food items and household public goods in the absence of transitory shocks to spending (10).

The role of longitudinal changes in individual earnings or household wealth on health over the life course in LMICs is less understood relative to high-income countries, primarily due to unavailability of longitudinal data. In LMICs, populations have experienced substantial changes but with persisting inequalities over the past five decades (11, 12). Existing literature on this topic has relied primarily on cross-sectional survey data that describe aggregate trends in household wealth using temporally valid asset indices, and do not directly quantify individual impacts of household level changes in wealth over time (13-17). Previous methodological advances for making household wealth comparable over time and geography include the

International Wealth Index (IWI), the Comparative Wealth Index (CWI) and the Absolute Wealth Estimate (AWE). However, their applicability has to date been restricted largely to serial cross-sectional studies. The IWI uses a common set of seven consumer durables, three housing characteristics and two public utilities in 165 cross-sectional surveys from 97 countries. The CWI was based on a reference Demographic and Health survey. The AWE was based on cross-sectional asset indices, national estimates of gross domestic product per capita and income inequality, expressed in 2011-constant dollars. While providing comparability over time and geography, due to the nature of the data sources, these measures do not permit exploration of long-term household-level changes in wealth that could aid in understanding the importance of life stage (such as early life, adolescence and early adulthood) and dimensions of SEP (wealth, schooling, employment) for later-life health outcomes (such as cardiovascular and metabolic disease) and wellbeing at an individual level (18). Additionally, such studies could contribute towards understanding the role of life course wealth in health disparities that are present in adulthood. Given the pace of the economic, demographic and epidemiological transitions experienced by LMICs, it is important to study wealth mobility over the life course and how it is associated with health outcomes later in life. Under assumptions of assets as public goods, household wealth reflecting an individual's wealth, similar asset loadings over time, and empirical demonstration of rank similar to standard cross-sectional approach, we may estimate these associations even if individuals were to change households (such as following adoption, migration or marriage).

Our objective was to develop a temporally-harmonized asset index over the life course for LMIC birth cohorts and assess its construct validity (i.e., the extent to which it ranks individuals on their socio-economic position) as well as robustness (i.e., the extent to which results are similar across alternate specifications of assets, survey years and factor extraction procedures) (13, 14). Such an index would allow researchers to compare wealth at different stages over the life course on the same measurement scale. The birth cohorts are part of the Consortium for Health Oriented Research from Transitioning Societies (COHORTS) collaborative (19). The cohorts are from five countries across three continents that have experienced different trajectories of economic development (**Supplementary Fig 4.1**).

We compared the temporally-harmonized index created in our study for each cohort with cross-sectional and regional (urban, rural) indices as per standard practice in epidemiological studies (20). We assessed if the harmonized index displays construct validity using maternal schooling and attained schooling. We also assessed the extent of generalizing findings to similar settings by assessing the robustness of the temporally-harmonized index to alternate specifications derived from including specific assets (shorter data collection instruments) and years of data collection (unmeasured effect modification by age or period effects) or different factor extraction procedures.

Methods

Study Population

We used all available information on assets collected over the life course for each of 5 birth cohorts - Brazil (Pelotas 1993), Guatemala (INCAP Longitudinal Study), India (New Delhi Birth Cohort), Philippines (Cebu Longitudinal Health and Nutrition Survey) and South Africa (Birth to Twenty plus cohort). The cohorts are representative of urban areas (Brazil, India, and South

Africa) or a mix of urban and rural areas (Guatemala, Philippines) in these countries. We present a detailed description of study waves used for each cohort in **Table 4.1**. For the INCAP Longitudinal Study cohort (from Guatemala), which includes multiple individuals from the same household, we conducted our analysis at the household level. All other cohorts consisted of only one participant per household.

The 1993 Pelotas (Brazil) cohort includes 5249 children born in the 1993 calendar year in the city of Pelotas. Study visits in childhood systematically targeted subsamples of cohort members residing in the city (21). The Institute of Nutrition for Central America and Panama (INCAP) conducted a nutrition supplementation cluster-randomized trial to study the role of early life protein and energy supplementation on growth and human capital from 1969 to 1977 in Guatemala (22). The trial was conducted in four villages of Department of El Progreso and the sample consisted of 2392 rural ladino (non-indigenous) residents of the study villages born between 1962 and 1977. The New Delhi Birth Cohort (India) consists of 8181 singleton births to married women in 1969-72 (23). The Cebu Longitudinal Health and Nutrition Survey (Philippines) consisted of all pregnant women from a single-stage cluster-sample of 17 urban and 16 rural barangays in Metro Cebu in 1983 (24). Among the 3327 women interviewed at baseline, the sample consisted of 3080 singleton and 26 multiple births followed-up during subsequent waves. The Birth to Twenty plus study (South Africa) consists of 3273 singletons who were residents of Soweto-Johannesburg (urban) born during a 7-week enrollment period in 1990 (25).

All participants (or their parent, as appropriate) provided written informed consent prior to participation at each study wave. We obtained ethical approval from the Institutional Review Board of Emory University (Protocol 95960) for this analysis.

Indicators of wealth

Information on assets and housing characteristics (such as building material and type of toilet) were collected over the life course until they became irrelevant or negligible in value. New assets were added over time to reflect the changing pattern of wealth-defining asset ownership in each society. Assets which were no longer relevant were not collected, so the number and type of assets were variable across study waves. Detailed information on asset availability for each cohort is presented in **Supplementary Tables 4.1 to 4.5**.

We included ownership (yes/no) of assets such as television, radio and washing machine as well as house ownership and electricity provision. We characterized housing by building material and type of toilet into ordinal variables (Low, Medium, High) based on site-specific definitions. We defined crowding as number of bedrooms per household member for Brazil, Guatemala, and Philippines such that a higher number represents greater wealth (26). This is unlike the typical definition for crowding, which is household members per room.

Statistical Analysis

We conducted all analysis at the household level, separately by cohort. We compared early life characteristics of cohort participants by participation in study wave. For the temporally-harmonized index, we considered all assets that were collected across all waves or were at most missing in one wave only. The list of assets considered varied by cohort. Within a cohort, we imputed the value for a missing asset for a wave based on the preceding study wave for those households that participated in that wave. For households that did not participate in the preceding wave, we imputed the missing value with the cross-sectional mode.

We performed a principal component analysis (PCA) on the polychoric correlation matrix derived after pooling study waves for each cohort (27). PCA is a statistical procedure which projects observed data into a set of orthogonal principal components such that the first component explains the most variance in the data. We extracted the first component as the harmonized index. Additional information on the analytic procedure is available in **Supplementary Note 4.1**. The polychoric correlation assumes a normally distributed latent variable that underlies an observed binary or ordinal variable. A harmonized index that was inversely weighted by the size of the analytic sample at each study wave was similar ($r = 1.00$; results not shown) to the unweighted harmonized index.

We visually assessed the harmonized index at each study wave for clumping (many households having the same value of the index). We also visually examined the index for truncation, whereby the index fails to differentiate heterogeneity in asset ownership across households/individuals at high or low levels of the index. To resolve these issues would require including assets that are able to differentiate such observations along the index (13). However, such assets were not available over the life course.

Validation of harmonized index

To examine how our benchmark harmonized index performed relative to standard practice, we assessed the Spearman rank correlation with separate cross-sectional indices constructed using the same set of assets. We also created cross-sectional indices by urban and rural residence of cohort members when relevant (Guatemala, Philippines). We conducted this analysis because there is an implicit assumption for the harmonized index that material goods have the same meaning over time for a cohort. We also assessed the rank correlation of the temporally-harmonized index with cross-sectional indices created using all available assets for each study wave after removing those displaying near zero variances (prevalence ratio > 95:5). To examine the degree of similarity of asset loadings over time, we calculated the Tucker coefficient of congruence (phi; same: greater than 0.95, high: 0.90 to 0.95, moderate: 0.85 to 0.89) between the harmonized index and each cross-sectional asset index created using the same set of assets after deleting zero-variance assets.

Finally, among those who participated in adulthood waves, we assessed the correlation of maternal schooling (collected in early life) and the participant's own attained schooling (in adulthood) with the corresponding measures of the harmonized index.

Sensitivity Analysis

We assessed if the asset index was sensitive to inclusion of specific assets or to factor extraction procedure. We report the rank correlation of our harmonized index with indices created after dropping assets and study waves as well as using an alternate correlation matrix (Pearson) with different factor extraction (Exploratory Factor Analysis, Multiple Correspondence Analysis) procedures. We categorized all ordinal variables (Low or Medium versus High) into binary variables for estimation of Pearson correlation matrix. We additionally categorized continuous variables (crowding > 0.75 rooms per member set to one, otherwise zero) into binary variables for the Multiple Correspondence Analysis.

We carried out all analysis using R 3.6.1 and 'psych' package v1.9.12.

Results

Information on a consistent set of durable assets and housing characteristics were available for each of the five birth cohorts over their life course (**Supplementary Table 4.1 to 4.5**; range of included assets 10 in South Africa to 30 in Philippines). Ownership of assets varied over time. The extent of ownership of electronic goods and quality of housing characteristics increased over time in all cohorts. Comparison of early life characteristics between children in all recruited households and children in households where asset data were unavailable (because the child did not participate or died) suggested that they were similar in Brazil, India, Philippines and similar on most characteristics in Guatemala and South Africa (**Supplementary Tables 4.6 to 4.10)**. Those who did not provide asset data in Guatemala were more likely to be male and in South Africa were more likely to be of White or Indian ethnicity, relative to the original sample.

Harmonized index construction

The harmonized index explained 44.6%, 54.4%, 26.5%, 35.5% and 48.4% of the variance in the polychoric correlation matrix for the cohorts from Brazil, Guatemala, India, Philippines and South Africa, respectively (**Table 4.2**). Ownership of large electronic appliances such as television, refrigerator, microwave, air conditioner and computer, consistently contributed to high positive loadings, such that households that owned these assets had higher values of the asset index. Ownership of radio (in Brazil and Guatemala) and farm animals (poultry, cattle, other animals) in Philippines had negative loadings, such that over time the households that owned them had lower values of the asset index.

The temporally-harmonized asset index suggested that wealth improved over time on average (**Table 4.3**) for all birth cohorts (Brazil: -1.03 to 0.38; Guatemala: -1.31 to 0.91; India: -0.86 to

0.84; Philippines: -1.00 to 0.84; South Africa: -0.55 to 0.57). Though most households improved their living standards over time, there was heterogeneity in asset accumulation (**Figure 4.1**). Wealth heterogeneity between households (as measured by sample standard deviation; SD) at each wave was relatively stable between birth and adolescence except in Philippines (0.64 at 0y to 0.91 at 12-13y) and South Africa (1.00 at 0-2y to 0.85 at 12-13y). From adolescence to adulthood, wealth heterogeneity (SD) declined in all cohorts except Guatemala (0.42 at 10-25y to 0.66 at 40-57y). Wealth also increased for all cohorts as the participants grew older (**Figure 4.2**).

Visual inspection of the histograms of harmonized wealth **(Supplementary Fig 4.6 to 4.10**) at different study waves suggest clumping for Brazil (12 assets) and South Africa (10 assets). We also observed some left-truncation in Guatemala for 1967 (age 0-5y) and 1975 (age 0-7y) suggesting a failure to differentiate among the poorest households.

Validation of harmonized index

Our validation exercise suggested that cross-sectional asset indices restricted to the set of common assets used to construct the temporally-harmonized index were correlated with the harmonized index (**Table 4.4**). All correlations were greater than 0.90 except for Brazil in 2015 (r=0.83) and India in 1999-00 (r = 0.85) and 2016-19 (r = 0.82). Comparison of asset loadings of harmonized index to cross-sectional asset indices created using same set of assets suggest that loadings were the same for Philippines and South Africa, with moderate or high congruence (phi > 0.85) for most waves across other sites except India (**Supplementary Tables 4.11 to 4.15, Supplementary Table 4.16**).

Asset loadings varied over time, with some becoming common (like electricity or television in Philippines), others becoming rare (like radio in Guatemala) or being substituted with novel assets (like coolers with air conditioners in India). For example, in the cross-sectional index for Brazil in 2015, single-door refrigerator loadings were negative (-0.24 vs 0.54 in harmonized index) since households which possessed a duplex refrigerator (0.65 vs 0.67 in harmonized index) were less likely to possess a single-door refrigerator relative to previous waves. Cross-sectional indices created using all available assets for each study wave (**Supplementary Tables 4.11 to 4.15**) were also correlated with the harmonized index for all cohorts (Brazil: r = 0.78 to 0.96; Guatemala: r = 0.81 to 0.95; India: 0.75 to 0.93; Philippines: r = 0.92 to 0.99; South Africa: r = 0.84 to 0.96). The lower correlation of the harmonized index with cross-sectional indices could be due to three reasons: newer assets (such as employing a cleaner and clothes dryer in Brazil, or plasma TV and internet in India or microwave in South Africa), removing low-variance assets (such as car, motorcycle and sewage facility in Guatemala), or assets not being collected in some waves (such as radio, toilet and water source in South Africa in 2012-13). Cross-sectional indices (**Supplementary Table 4.17 to 4.19**) created for urban and rural strata were correlated with the temporally-harmonized index for Philippines (Rural: $r \geq 0.95$; Urban: $r \geq 0.98$) and Guatemala ($r \geq 0.95$).

Maternal schooling was correlated with harmonized asset index in childhood (r = 0.15 to 0.56) and school-age (r = 0.28 to 0.57) in for all cohorts (**Table 4.5**). Attained schooling was correlated (r = 0.18 to 0.54) with harmonized index in late-adolescence and early adulthood (15 to 40y) for all cohorts. Attained schooling was also correlated with harmonized index in middle adulthood for Guatemala (r = 0.45) and India (r=0.40 to 0.44). Correlations of harmonized wealth in childhood with height-for-age z-scores at 24 months ($r = 0.11$ to 0.27) were small but positive in three cohorts. Similarly, harmonized wealth in adulthood were correlated with adult body mass index ($r = 0.15$ to 0.21) in the older three (out of 5) cohorts. These findings, similar to that of cross-sectional wealth (**Supplementary Table 4.20**), suggest construct validity of the harmonized wealth measure.

Sensitivity analysis

The benchmark asset index was robust to pairwise dropping of assets (Brazil: $r \geq 0.95$; Guatemala: $r \geq 0.99$; India: $r \geq 0.85$; Philippines: $r \geq 0.99$; South Africa: $r \geq 0.91$) as well as survey years (Brazil: $r \geq 0.99$; Guatemala: $r =1.00$; India: $r \geq 0.88$; Philippines: $r = 1.00$; South Africa: $r \geq 0.99$). The index was also robust to joint dropping of asset and survey year (Brazil: $r \geq 0.96$; Guatemala: $r \geq 0.99$; India: $r \geq 0.85$; Philippines: $r \geq 0.99$; South Africa: $r \geq 0.97$). Additional information is available in **Supplementary File 4.1**.

Finally, the benchmark asset index was invariant to alternate factor extraction procedures (**Supplementary Table 4.21**). Asset indices created using Exploratory Factor Analysis with polychoric ($r \geq 0.94$) or Pearson's correlation ($r \geq 0.94$) matrix, Principal Components Analysis using Pearson's correlation matrix ($r \geq 0.99$) or Multiple Correspondence Analysis ($r \geq 0.98$) were rank correlated with the benchmark index for all countries.

Discussion

Our results suggest that a harmonized index, created using consistently collected measures of asset ownership and housing characteristics, may be used to study trajectories of household wealth mobility within birth cohorts from LMIC settings. Such a temporally-harmonized asset index could then be used to study the association of wealth gains at different stages of the life course with health and wellbeing outcomes in later life (28). Across all cohorts, households acquired additional assets and improved their housing characteristics over time. Previous research from our team used the INCAP cohort (Guatemala) to develop the approach for temporally harmonized index construction and validation (29). Our results from this analysis complements previous research by generalizing findings that temporally harmonized asset indices, created from a shorter set of assets for cohort studies, are rank-correlated with the standard approach of creating asset-based indices across different geographical contexts (28, 30, 31). The temporally harmonized asset index, created for cohort studies, using consistently collected set of assets, complements previous research that studied how mean household wealth improved over time across different countries using cross-sectional nationally-representative surveys (13, 14, 32).

Our results also suggest that an index created from a subset of these assets was correlated with the cross-sectional asset indices (created using all available assets) used in epidemiological studies as a proxy for wealth and standard of living. The harmonized index also correlated with cross-sectional indices created separately for urban and rural samples in Philippines and Guatemala. The mean values of harmonized index in urban areas were higher than rural areas for all study years in Guatemala and Philippines (results not shown). The harmonized index also displayed construct validity when compared with maternal schooling and attained schooling in early life and adulthood respectively.

We observed clumping in Brazil and South Africa due to unavailability of consistently collected assets that could adequately differentiate households. We observed left-truncation in the earlier study waves (in 1967 and 1975) from Guatemala potentially due to unavailability of assets that are able to differentiate between poor households. One reason for this is that our cohort originally belonged to rural villages that were predominantly reliant on agriculture, and gradually transitioned to manufacturing and service sector jobs over time (33, 34). Asset-based indices are known to be biased against households that derive livelihoods from the agricultural economy. Households within these villages being uniformly poor at the beginning of the study could be another reason for the observed distribution (34).

The harmonized index was correlated with indices derived from dropping pairs of assets or survey years as well as combinations of asset and survey year, consistent with the International Wealth Index and results from the Millennium Villages Project (13, 35). Also consistent with other studies, an index extracted using PCA of the polychoric correlation matrix was highly correlated with indices extracted using other approaches (Exploratory Factor Analysis, Multiple Correspondence Analysis) (7, 35-37). Moreover, assets related to livestock, i.e., poultry, cattle and farm animals, had negative loadings on the harmonized index as well as cross-sectional indices for Philippines (but loaded on other components), similar to research from South Africa and Kenya (38-41). Dropping these assets did not change our results. However, our index may fail to capture non-engagement with the modern cash-oriented sectors (but engaged with the agricultural sector) by some cohort members who possessed substantial livestock wealth (42).

Limitations

The index has limitations inherent to the longitudinal nature of our study. The harmonized asset index assumes that the structure of interrelationships among different assets is similar over time.

However, the same asset changes in importance over time as it becomes ubiquitous or less common. Our analysis of congruence suggests that the harmonized index is similar to the cross-sectional index for most study waves. Though all birth cohorts experienced significant attrition over the life course, comparison of early life characteristics of cohort members who did not participate suggested that they were otherwise similar. Additionally, since the index is relative and country-specific, it does not explain the association of absolute wealth gains (such as savings or debt) across the life course with health outcomes. Such studies have been attempted in a limited way across geographies such as in the analysis of cross-sectional measures of income (such as gross national income per capita adjusted for purchasing power parity) or household wealth with child height and adult overweight (6, 43-45). The positive association between wealth and BMI in adulthood in Guatemala, India and Philippines is consistent with wider literature that suggests countries earlier in the nutrition transition exhibit a positive association between socioeconomic position and BMI (6).

Since our analysis was restricted to assets collected over the life course, we could not include newer electronic goods such as digital tablets and laptops. Data on assets were not available in early life for India. The limited availability of asset data also prevented us from inferring if other metrics associated with assets – quantity, quality or functioning, technological generation, availability of substitutes – biased our findings (9, 46). Our sensitivity analysis using data from the Pelotas 1993 (Brazil) cohort suggested that a harmonized asset index created using counts of assets such as televisions, cars and housekeepers as well as number of bathrooms in the house was correlated (r = 0.98) with the benchmark asset index. Similar to cross-sectional surveys, we assume that all assets are public goods, i.e. available to all members in the household and except for number of rooms per member, do not adjust for household size and composition (27). We do not account for selection of individuals into households with higher/lower asset index (e.g. from rural to urban areas for employment) and changing households (e.g. for marriage) that could result in scores that are different from what would be concurrently experienced by their original family unit (household of birth).

Conclusion

Temporally-harmonized asset indices open up opportunities for longitudinal investigation of the impact of early life wealth on later life health outcomes. Such indices allow comparison of wealth at different life stages in the same measurement unit under assumptions of temporal validity. Previous studies exploring the link between economic and epidemiological transition rely on measures of material well-being which are ecological such as Gross National Income per capita (3) or cross-sectional wealth (6). However, household wealth (both relative and absolute) at different stages of life course may determine behaviors such as physical activity or diet or psychosocial resources such as self-efficacy and life satisfaction that are associated with health (47, 48). Exploring the association of household wealth with health at different stages of the life course could also aid in designing social safety nets targeting specific health outcomes. Moreover, studies in LMICs exploring the roles of these downstream pathways (such as health behaviors and psychosocial stressors) may be confounded by life course wealth (and other measures of SEP) which ought to be quantified.

Consistently administered and contextually relevant measures of wealth may inform design of interventions and better estimation of long-term effects of life course exposures on health and human capital in low- and middle-income countries.

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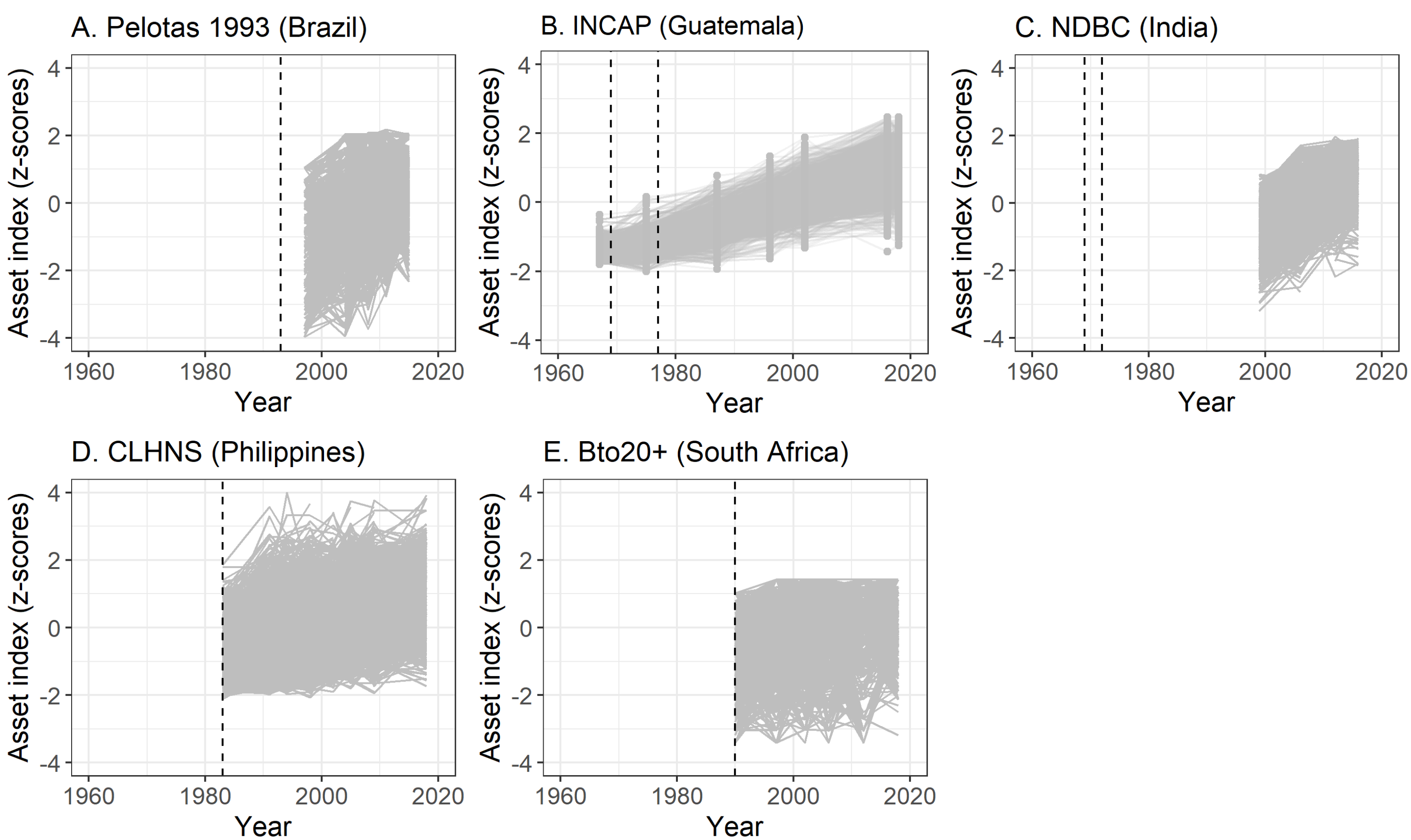
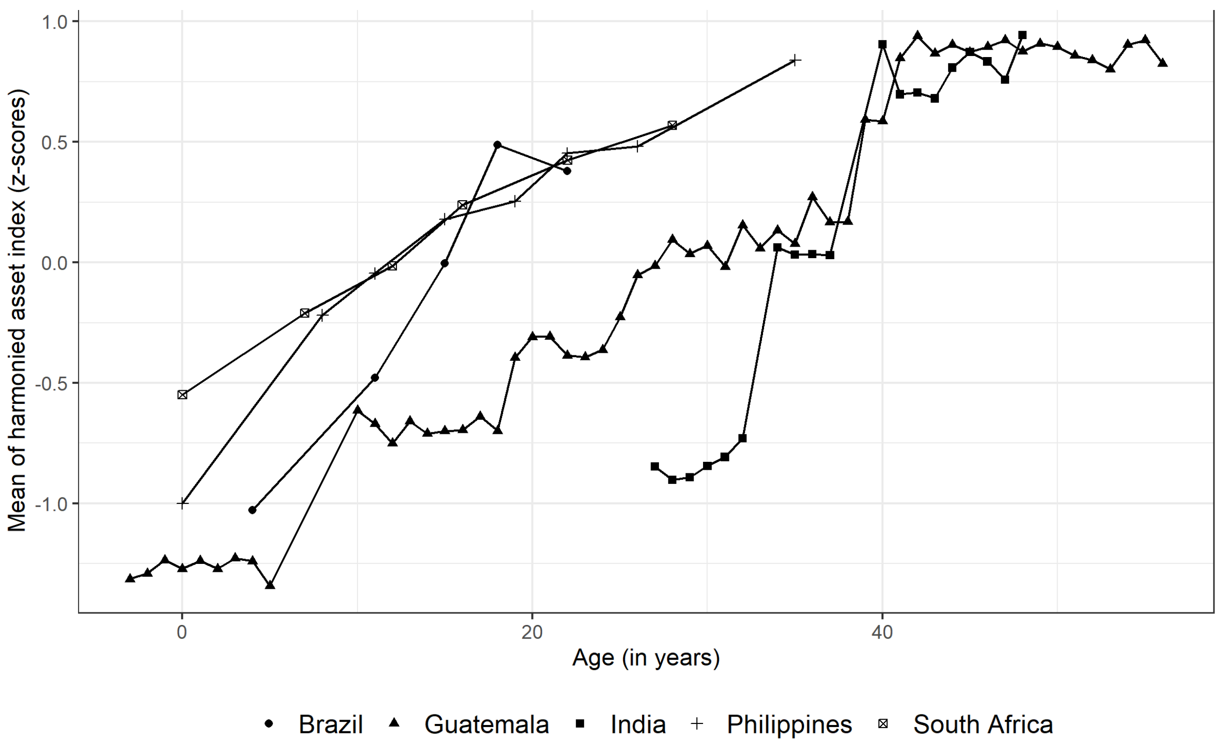
Figure 4.1 Household-level trends in temporally-harmonized asset index for birth cohorts from low- and middle-income countries



X-axis range (in calendar years) represents duration of cohort. Dotted lines indicate beginning of cohort study for each site.

Figure 4.2 Mean trends in temporally-harmonized asset index for birth cohorts



All values are mean values from a harmonized index created separately for each cohort. Only mean values at ages where number of observations are greater than 30 are plotted. Guatemala has age ranges of 0-5 in 1967 and 0-7 in 1975 which have been combined (ages less than zero indicate those born after data collection). The number of data points above for Guatemala (1962-1977) and India (1969-1972) is a result of the wide range of birth years. Missing birth years were imputed with median of data collection (i.e. 1971) in India.

Table 4.1 Percentage of birth cohort with valid asset data at each study wave

		Pelotas 1993 (Brazil)[a]		INCAP (Guatemala)[b]		NDBC (India)[c]		CLHNS (Philippines)		Birth to Twenty plus (South Africa)
	Start of study	**N**	**Start of study**	**N**	**Start of study**	**N**	**Start of study**	**N**	**Start of study**	**N**
	1993	**5249**	**1969-77**	**2392**	**1969-72**	**8181**	**1983-84**	**3080**	**1990**	**3273**
	Age at wave	**%**	**Age at wave**	**%**	**Age at wave**	**%**	**Age at wave**	**%**	**Age at wave**	**%**
1	3-4	24.2%	0-5	67.0%	27-33	18.7%	0	100%	0-2	85.9%
2	11-12	84.3%	0-7	92.5%	34-40	14.0%	7-8	73.5%	7-8	41.1%
3	13-14	82.7%	10-25	56.9%	40-47	9.7%	12-13	71.0%	12-13	44.1%
4	18	78.2%	19-34	35.7%	44-51	10.3%	15-16	67.6%	16-17	46.2%
5	22	72.6%	25-40	44.0%			18-19	65.4%	22-23	50.0%
6			37-55	48.6%			21-22	61.2%	27-28	42.6%
7			40-57	52.9%			25-26	55.5%		
8							33-36	43.1%		

a Age 3-4 was a systematic sub-sample

b Village enumeration collected data on assets and housing characteristics only for those who lived there

c Early life waves did not collect asset data to include in this analysis.

Table 4.2 Loadings on temporally-harmonized index for assets and housing characteristics by cohort

	Pelotas 1993 (Brazil)	**INCAP (Guatemala)**	**NDBC (India)**	**CLHNS (Philippines)**	**Birth to Twenty plus (South Africa)**
Variance explained by PC1 (%)	**44.6%**	**54.4%**	**26.5%**	**35.5%**	**48.4%**
Rooms per person	0.32	0.44	0.29	0.33	-
Car	0.74	0.81	0.75	0.81	0.65
Computer	0.81	-	0.89	-	-
Duplex refrigerator	0.67	-	-	-	-
DVD player	0.77	-	-	-	-
Housekeeper	0.63	-	-	-	-
Radio	-0.19	-0.17	-0.24	-	0.48
Refrigerator	0.54	0.9	-	0.88	0.87
Television	0.84	0.94	0.02	0.75	0.81
Vacuum cleaner	0.77	-	-	-	-
Washing machine	0.77	-	0.66	-	0.83
Drinking water quality	0.62	0.81	0.12	0.53	0.64
Bicycle	-	0.59	0.35	0.36	-
Electricity	-	0.94	-	0.83	0.69
Two wheeler	-	0.72	0.03	-	-
Owns house	-	0.09	-	0.09	-
Sewing machine	-	0.46	-	-	-
Floor quality	-	0.87	-	-	-
Kitchen location	-	0.68	-	-	-
Roof quality	-	0.82	-	-	-
Sewage facility	-	0.81	-	-	-
Stove/Cooking fuel quality	-	0.84	-	0.82	-
Toilet quality	-	0.8	0.53	0.79	0.66
Wall quality	-	0.85	-	-	-
Air conditioner	-	-	0.89	0.80	-
Cable TV	-	-	-0.44	-	-

Cell phone	-	-	0.81	-	-
Cooler	-	-	-0.53	-	-
Dish TV	-	-	0.83	-	-
Mixer grinder	-	-	0.57	-	-
Telephone	-	-	0.01	-	0.43
Sharing of drinking water source	-	-	-0.01	-	-
General water	-	-	0.07	-	-
Sharing of general water source	-	-	-0.14	-	-
Poultry	-	-	-	-0.18	-
Electric fan	-	-	-	0.78	-
Electric iron	-	-	-	0.87	-
Jeepny	-	-	-	0.65	-
Living room set	-	-	-	0.71	-
Other appliances	-	-	-	0.38	-
Cleanliness of area where food is stored	-	-	-	0.49	-
Garbage disposal	-	-	-	0.36	-
Condition of area for excreta	-	-	-	0.25	-
Lighting	-	-	-	0.91	-
Housing material	-	-	-	0.66	-
Neighborhood excreta removal	-	-	-	0.56	-
Neighborhood garbage removal	-	-	-	0.61	-
Beds	-	-	-	0.70	-
Boat	-	-	-	-0.02	-
Cattle (cows or carabaos)	-	-	-	-0.32	-
Farm animals (goat, horse, pigs etc)	-	-	-	-0.31	-
Other vehicles (banca, motorcycle or tricycle etc)	-	-	-	0.18	-
Truck or bus	-	-	-	0.52	-
Microwave	-	-	-	-	0.76

Harmonized asset indices were created separately for each site.

Table 4.3 Summary of harmonized index over time for COHORTS

		Pelotas 1993 (Brazil)		INCAP (Guatemala)		NDBC (India)		CLHNS (Philippines)		Birth to Twenty plus (South Africa)
	Age at wave	**Summary**	**Age at wave**	**Summary**	**Age at wave**	**Summary**	**Age at wave**	**Summary**	**Age at wave**	**Summary**
	Mean ± SD									
1	3-4	-1.03 +/- 1.15	0-5	-1.31 +/- 0.28	27-33	-0.86 +/- 0.65	0	-1.00 +/- 0.64	0-2	-0.55 +/- 1.00
2	11-12	-0.48 +/- 1.06	0-7	-1.15 +/- 0.34	34-40	0.03 +/- 0.79	7-8	-0.20 +/- 0.92	7-8	-0.21 +/- 0.90
3	13-14	-0.00 +/- 0.88	10-25	-0.69 +/- 0.42	40-47	0.72 +/- 0.75	12-13	-0.05 +/- 0.91	12-13	-0.01 +/- 0.85
4	18	0.49 +/- 0.75	19-34	-0.12 +/- 0.47	44-51	0.84 +/- 0.67	15-16	0.18 +/- 0.90	16-17	0.24 +/- 0.88
5	22	0.38 +/- 0.66	25-40	0.15 +/- 0.53			18-19	0.25 +/- 0.80	22-23	0.42 +/-0.91
6			37-55	0.85 +/- 0.68			21-22	0.45 +/- 0.84	27-28	0.57 +/- 0.80
7			40-57	0.91 +/- 0.66			25-26	0.48 +/- 0.84		
8							33-36	0.84 +/- 0.86		
	Median [IQR]									
1	3-4	-0.85 [-1.26, -0.43]	0-5	-1.31 [-1.53, -1.08]	27-33	-0.88 [-1.19, -0.34]	0	-1.15 [-1.48, -0.67]	0-2	-0.47 [-1.22, 0.20]
2	11-12	-0.67 [-1.16, 0.08]	0-7	-1.10 [-1.38, -0.96]	34-40	0.12 [-0.59, 0.63]	7-8	-0.27 [-0.96, 0.43]	7-8	-0.15 [-0.74, 0.42]
3	13-14	0.01 [-0.70, 0.52]	10-25	-0.67 [-0.94, -0.43]	40-47	0.85 [0.23, 1.32]	12-13	-0.04 [-0.70, 0.63]	12-13	0.03 [-0.52, 0.57]
4	18	0.54 [0.09, 0.98]	19-34	-0.14 [-0.42, 0.20]	44-51	0.98 [0.47, 1.34]	15-16	0.24 [-0.47, 0.83]	16-17	0.34 [-0.33, 0.98]
5	22	0.44 [0.00, 0.85]	25-40	0.09 [-0.20, 0.50]			18-19	0.28 [-0.30, 0.80]	22-23	0.61 [0.03. 1.06]
6			37-55	0.83 [0.37, 1.35]			21-22	0.46 [-0.15, 0.98]	27-28	0.83 [0.12, 1.20]

7			40-57	0.92 [0.48, 1.38]			25-26	0.46 [-0.06, 0.97]		
8							33-36	0.77 [0.27, 1.37]		

Table 4.4 Correlation of harmonized index with cross-sectional indices created from same set of assets for COHORTS

		Pelotas 1993 (Brazil)		INCAP (Guatemala)		NDBC (India)		CLHNS (Philippines)		Birth to Twenty plus (South Africa)
	Age at wave	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**
1	3-4	0.96	0-5	0.95	27-33	0.85	0	0.99	0-2	0.99
2	11-12	0.97	0-7	0.91	34-40	0.93	7-8	1.00	7-8	0.99
3	13-14	0.98	10-25	0.92	40-47	0.91	12-13	0.99	12-13	0.99
4	18	0.99	19-34	0.96	44-51	0.82	15-16	0.99	16-17	0.99
5	22	0.83	25-40	0.98			18-19	0.99	22-23	0.95
6			37-55	0.99			21-22	0.99	27-28	0.98
7			40-57	0.98			25-26	0.99		
8							33-36	0.99		

All values are Spearman rank correlations. Correlation of harmonized index with cross-sectional indices created from all available assets is available in **Supplementary Tables 3A-E**.

Table 4.5 Correlation of schooling and health measures with harmonized asset index in corresponding wave among those who participated in adulthood

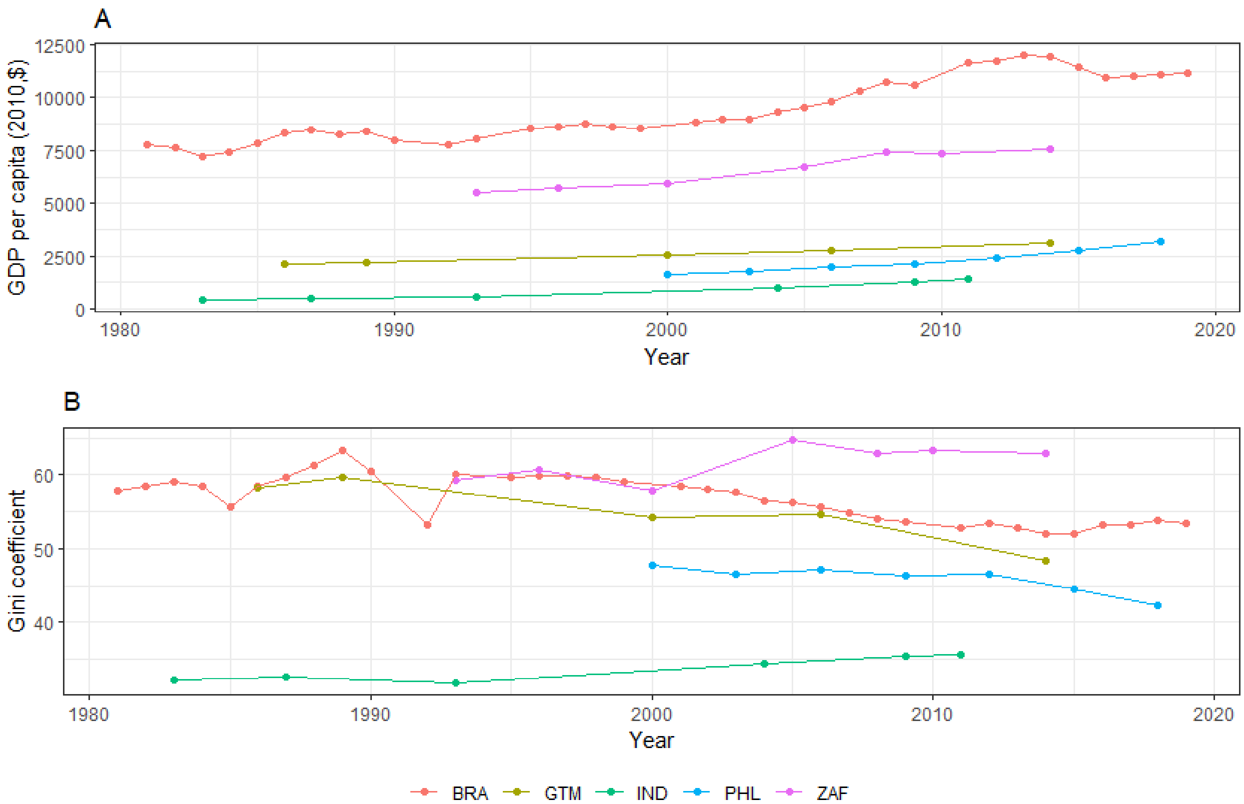
		Pelotas 1993 (Brazil)		**INCAP (Guatemala)**		**NDBC (India)**		**CLHNS (Philippines)**		**Birth to Twenty plus (South Africa)**
	Age at wave	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**	**Age at wave**	**rho**
Schooling										
1	3-4[a]	0.54	0-7[a]	0.15	0-2[b]	Not available	0[a]	0.56	0-2[a]	0.23
2	11-12[a]	0.57	10-25	0.31	27-33	0.44	7-8[a]	0.56	7-8[a]	0.28
3	13-14[a]	0.56	19-34	0.31	34-40	0.46	12-13[a]	0.54	12-13[a]	0.29
4	18	0.45	25-40	0.36	40-47	0.40	15-16	0.50	16-17	0.18
5	22	0.42	37-55	0.45	44-51	0.44	18-19	0.52	22-23	0.18
6			40-57	0.45			21-22	0.52	27-28	0.23
7							25-26	0.54		
8							33-36	0.53		
HAZ at 2y										
9	2[b]	Not available	2	0.11	2[b]	Not available	2	0.27	2	0.13
BMI in adulthood										
10	22	-0.05	37-55	0.15	44-51	0.21	33-36	0.19	22-23	0.06

Sample sizes among those who participated in adulthood varied for above Pearson correlations: Brazil (995;3608;3576;3519;3805;3559), Guatemala (1346;931;641;821;1160;1265;723;1143), India (868;807;790;841;828), Philippines (1326; 1321; 1325; 1325; 1303; 1311; 1274; 1249; 1326; 1285;1304), and South Africa (1132;999;1071;1201; 1274; 1393; 856; 1202). This is not the sample size of participants at each wave (non-monotone missingness).

a Correlation with maternal schooling. Values from 1967 and 1975 were combined for Guatemala (n = 2392).

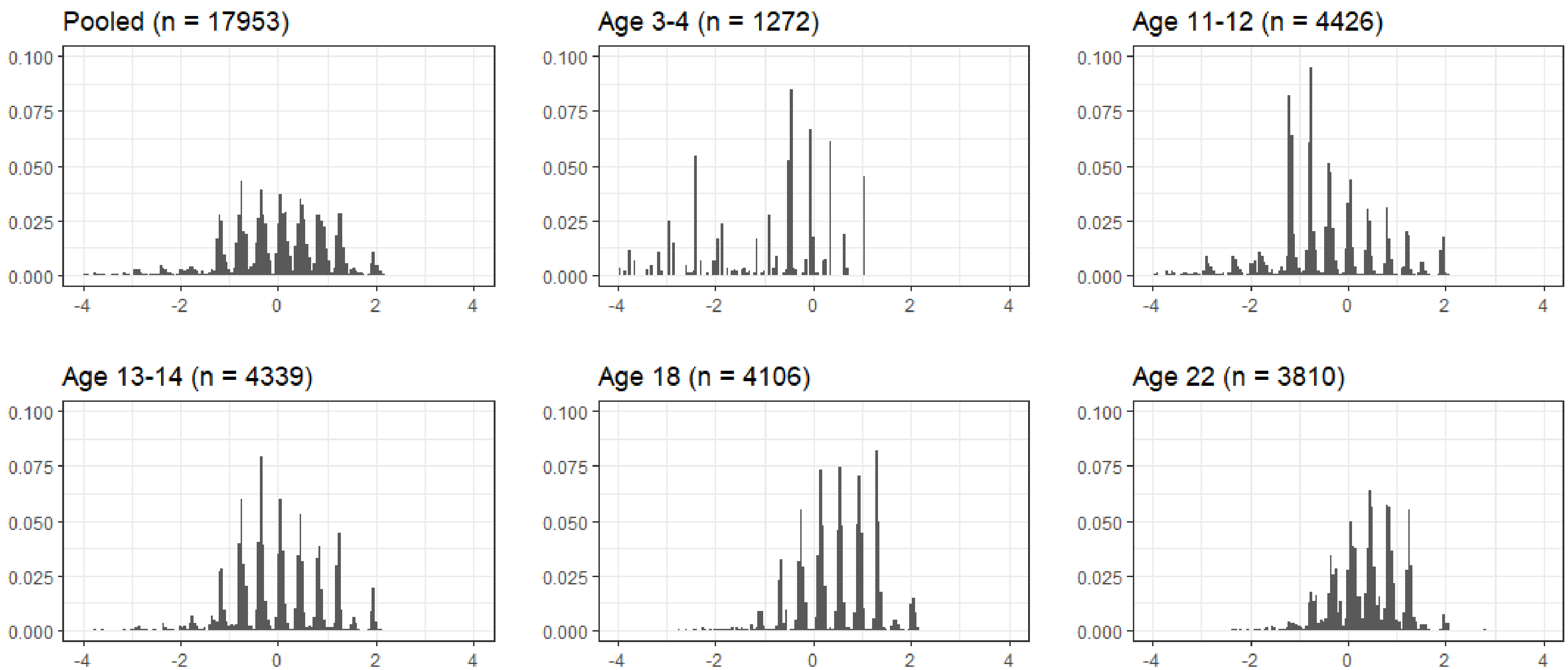
b Temporally harmonized asset index was not available in childhood for NDBC and before 3 years for Pelotas 1993

Supplementary Figure 4.1 Trajectories of gross-domestic product (GDP) per capita and Gini index for five low- and middle-income countries

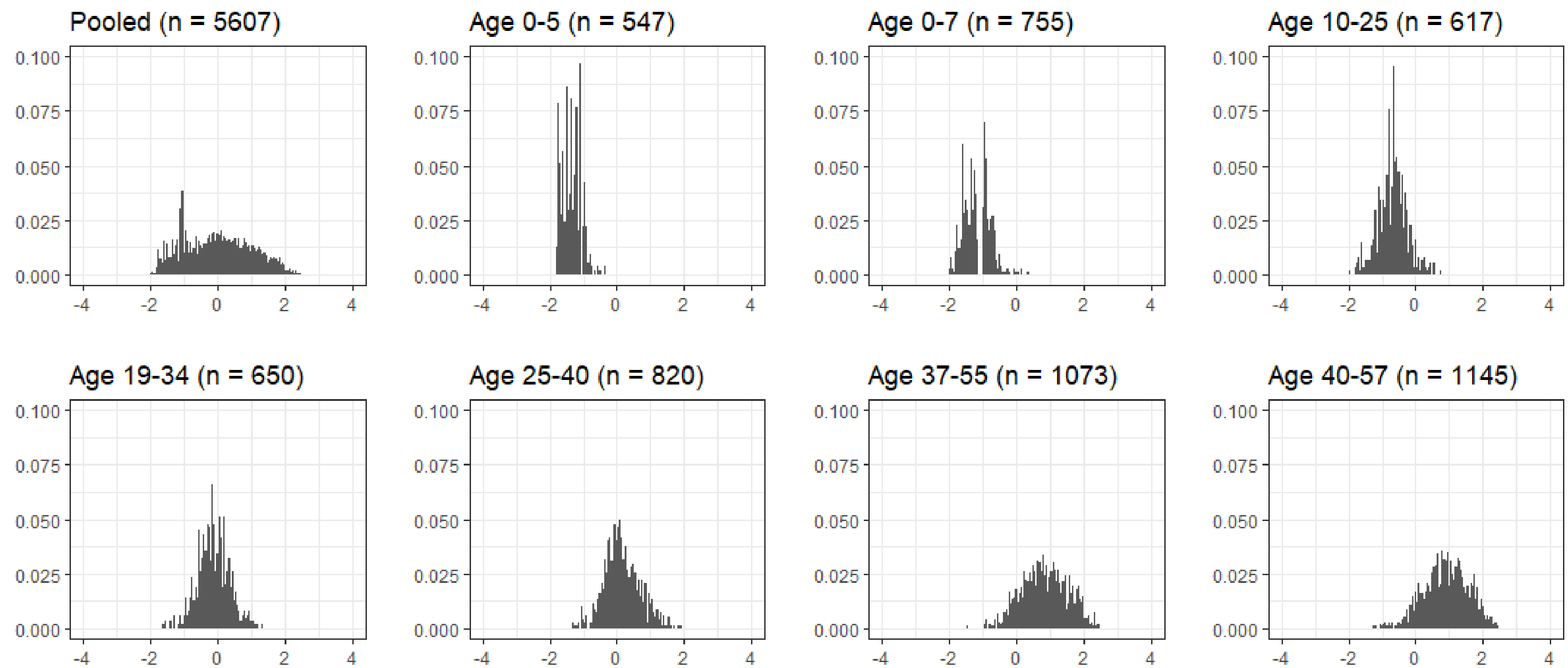


Data from World Bank World Development Indicators

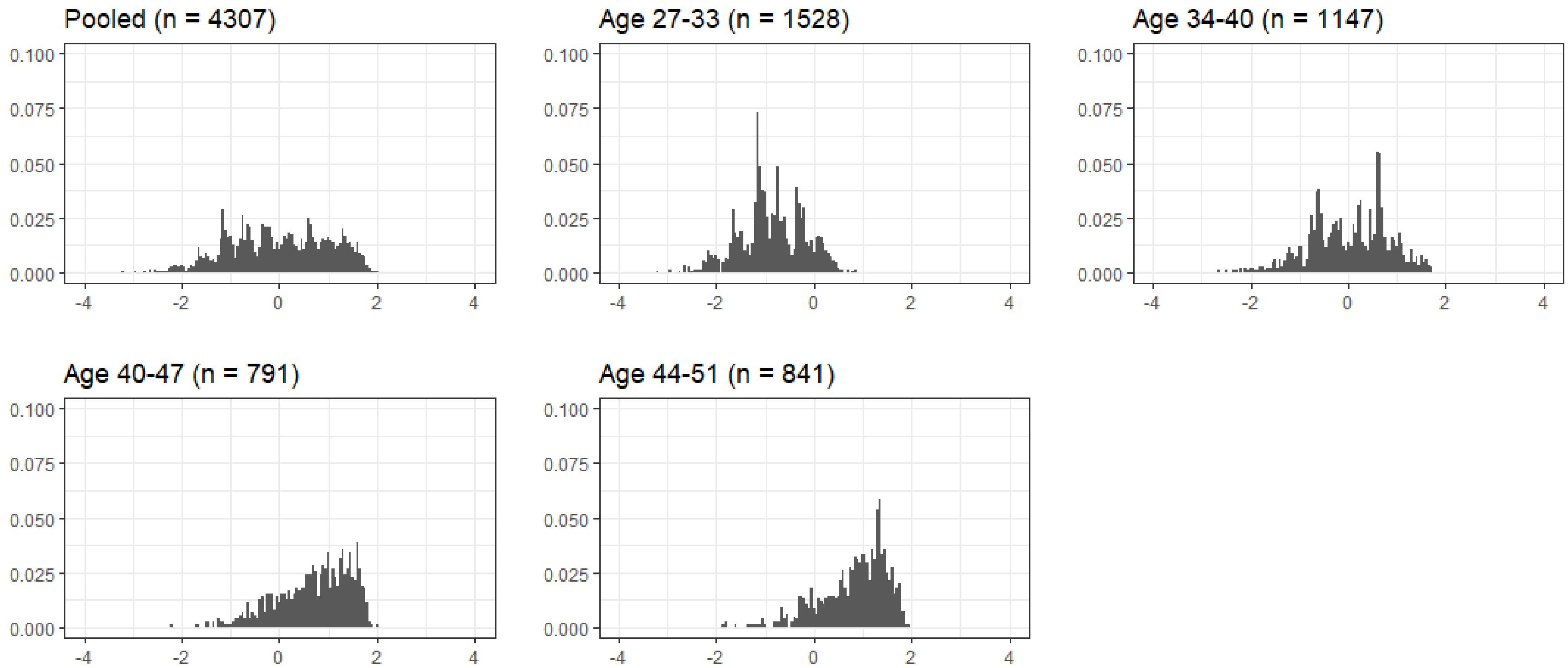
Supplementary Figure 4.2 Distribution of harmonized wealth index over time in Pelotas 1993 cohort by study wave



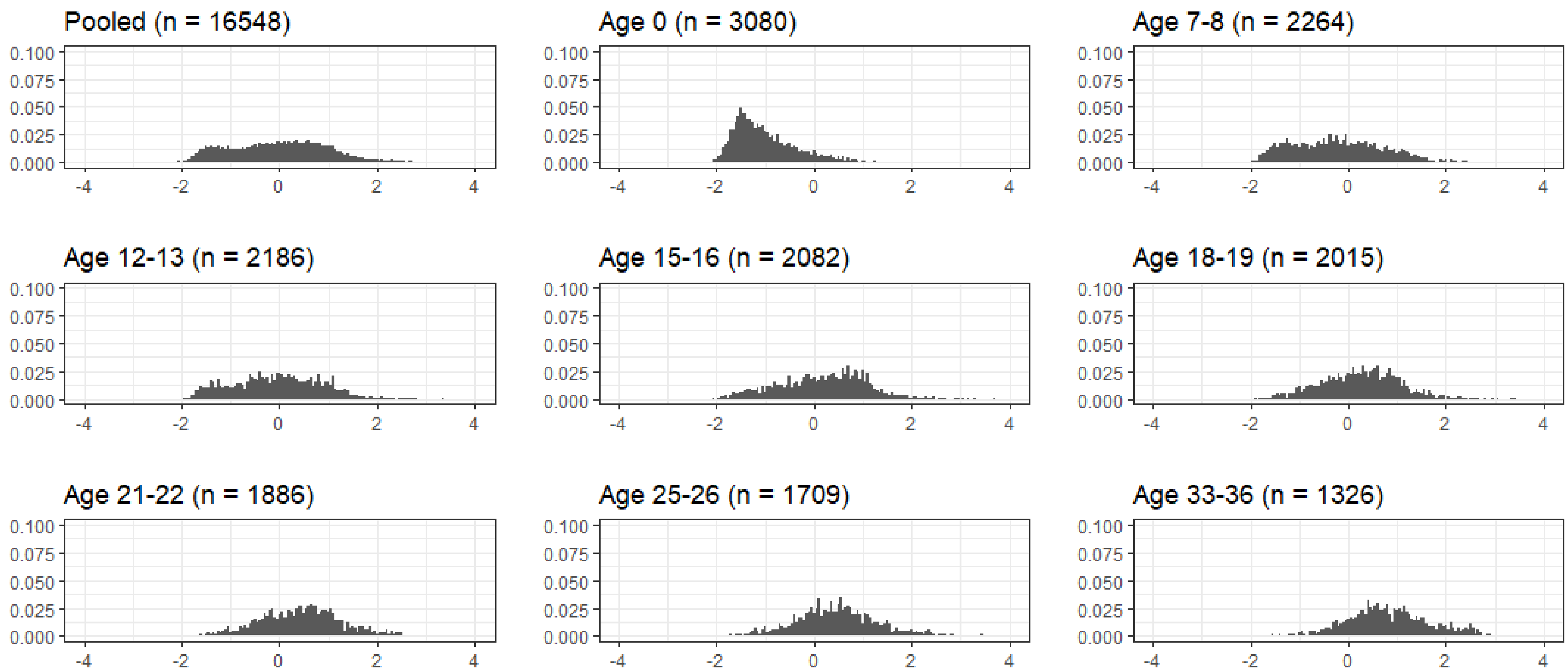
Supplementary Figure 4.3 Distribution of harmonized wealth index over time in INCAP Longitudinal Study cohort by study wave



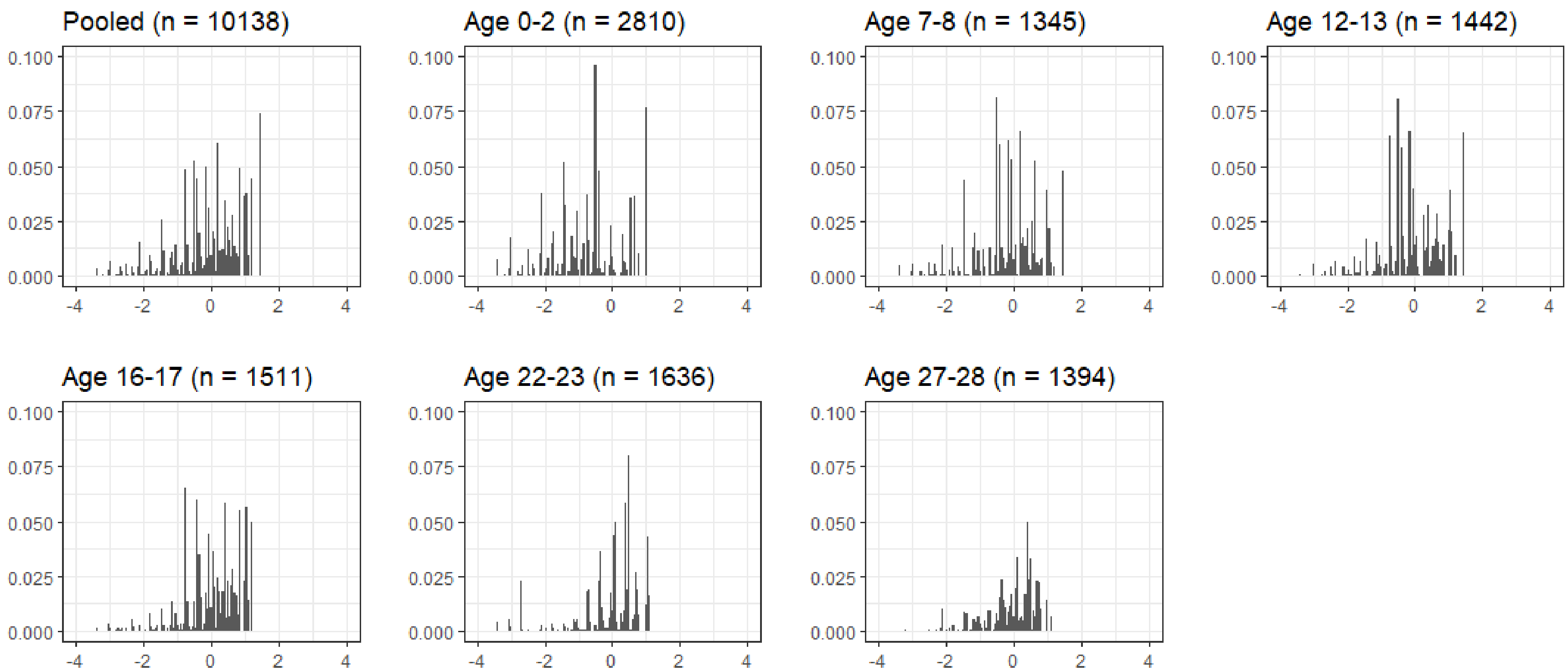
Supplementary Figure 4.4 Distribution of harmonized wealth index over time in New Delhi Birth cohort by study wave



Supplementary Figure 4.5 Distribution of harmonized wealth index over time in Cebu Longitudinal Health and Nutrition Study by study wave



Supplementary Figure 4.6 Distribution of harmonized wealth index over time in Birth to Twenty plus cohort by study wave



Supplementary Note 4.1 Detailed statistical methods

A. Description of statistical procedure used in estimation of temporally harmonized index

We followed the following steps to construct the harmonized index across study waves (henceforth 'waves') over the life course. Individuals were the unit of analysis (except for Guatemala where we used households), and analyses were restricted to individuals who participated in the study wave. Our analysis for the harmonized index was on a pooled dataset across all waves separately for each cohort.

1. All assets and housing characteristics (henceforth 'items') available for each cohort was harmonized by categorizing them into ownership (yes/no; binary), quality (low/medium/high; ordinal) or quantity (counts; integer/continuous) variables.

2. We then identified those items that were available in all waves, or missing in at most one wave. These items were considered for further analysis.

3. Imputation: We imputed the items that were missing in an entire wave with the preceding wave for those individuals who participated in both waves. If an individual did not participate in the preceding wave, we imputed the value with the cross-sectional mode. If an item was missing in the first wave, we imputed it with zero. We assessed robustness of the index at a later stage by dropping two assets and study years at a time.

4. We constructed a mixed correlation matrix (Pearson for continuous, polychoric for ordinal, tetrachoric for binary, polyserial/biserial correlations for ordinal/binary with continuous) for the imputed dataset.

5. We used principal component analysis (PCA) and extracted the first component as the harmonized index. We standardized the index (to unit variance) the component by subtracting by the pooled mean and dividing by standard deviation.

B. Description of statistical procedure used for sensitivity analysis for cross-sectional indices

1. We identified all assets that were available in a cross-sectional wave as part of the sensitivity analysis comparing the harmonized index with the normative cross-sectional indices.

2. We imputed the value of an item with the cross-sectional mode for those who did not provide information in the cross-sectional wave or the preceding wave for cross-sectional indices similar to the harmonized index. For the normative cross-sectional indices that include all assets collected in a wave, we included only those assets which were collected in the wave and imputed missing values with the mode.

3. We removed those variables which displayed near-zero variance (ratio of most common to second most common category > 95:5). We limited our analysis to variables that displayed sufficient variance in the data. This was different from the harmonized index wherein we included all variables irrespective of their variance.

4. We constructed a mixed correlation matrix (Pearson for continuous, polychoric for ordinal, tetrachoric for binary, polyserial/biserial correlations for ordinal/binary with continuous) for the imputed dataset.

5. We used principal component analysis (PCA) and extracted the first component as the harmonized index. We standardized the index (to unit variance) the component by subtracting by the pooled mean and dividing by standard deviation.

Supplementary Table 4.1 Categorization and availability of assets for Pelotas 1993 cohort by study wave

	Survey Year	**1997**	**2004**	**2008**	**2011**	**2015**			
	Percentage of original sample with asset data	24.2%	84.3%	82.7%	78.2%	72.6%			
Asset	**Categorization**								
Car	Yes, No	30.7	35.3	37.7	46.2	57.9			
Computer	Yes, No		16.9	45.1	76.7	76.8			
Duplex refrigerator	Yes, No		28.9	35.6	44.2	52.2			
DVD player	Yes, No	32.5	37.2	81.2	92.9	78.5			
Housekeeper	Yes, No	9.3	6.3	5.4	5.5	2.8			
Radio	Yes, No	91.6	89.8	90.3		74.1			
Refrigerator	Yes, No	87.8	91.7	94.9	99.1	92.8			
Television	Yes, No	82.4	93.3	98.3	99.2	99.5			
Vacuum cleaner	Yes, No	18.6	22.7	27.0	44.3				
Washing machine	Yes, No	46.5	60.2	64.5	75.3	80.8			
Piped water	Low: Not available, Other location	3.5	1.1	0.8		0.3			
	Medium: In courtyard, artesian well/spring	4.6	2.2	0.8		1.7			
	High: Inside home, general distribution network	91.8	96.7	98.4		98.0			
House ownership	Yes, No		81.4	83.2	86				
Housing material	Low: Cardboard/tin, clay, canvas, Other	0.1	4.1						
	Medium: Wood (regular/irregular),	20.9	19.8						

	mixed, brick without plaster								
	High: Brick with plaster, apartment	79.0	76.1						
Toilet	Low: None	8.3	2.1	0.9					
	Medium: Toilet without flush, Outside house/cesspool	7.5	2.6	1.4					
	High: Flush toilet	84.1	95.3	97.6					
Air conditioning	Yes, No				15.5	32.5			
Cleaning lady	Yes, No					6.2			
Clothes dryer	Yes, No					22.8			
Desktop	Yes, No				65.1				
Dishwasher	Yes, No					4.7			
Internet	Yes, No		76.7	71.3	82.4	85.2			
Microwave	Yes, No				62.5	78.1			
Motorcycle	Yes, No	8.9				34.1			
Notebook computer	Yes, No				38.8				
Stereo	Yes, No		64.9	63					
Street is paved	Yes, No					50.5			
Video game	Yes, No			33.6	45.4				

Supplementary Table 4.2 Categorization and availability of assets for INCAP Longitudinal Study cohort by study wave

	Survey Year	**1967**	**1975**	**1987**	**1996**	**2002**	**2015-16**	**2017-18**	
	Percentage of original sample with asset data	67.0%	92.5%	56.9%	35.7%	44.0%	48.6%	52.9%	
Asset	**Categorization**								
Bicycle	Yes, No	0.7	2.5	10.9	44.6	53.2	50.9	45.2	
Car	Yes, No		0.1	0.8	3.1	7.7	27	26.7	
Electricity	Yes, No	0.2	10.9	71.6	92	95.6	97.9	97.5	
Motorcycle	Yes, No		0.3	0.8	2	1.2	23.7	30.7	
House ownership	Yes, No	84.1	80	82.2	75.4	78.2	81.3	83.1	
Radio	Yes, No	32.2	52.8	58	72.8	21.1	30.2	21.6	
Refrigerator	Yes, No	0.5	2.4	3.9	15.1	27.2	67	71.3	
Sewing machine	Yes, No		10.7	10.2	10.8	10.4	19.2	18.2	
Television	Yes, No		0.9	22.4	65.8	77.1	92	92.3	
Floor quality	Low: Earth	96	88.6	62.9	37.2	23.7	9.9	9.2	
	Medium: Brick or clay, cement cake	4	8.9	32.7	53.1	59.9	55.2	57	
	High: Mosaic, wood		2.5	4.4	9.7	16.5	35	33.8	
Kitchen location	Low: No kitchen, in bedroom	42.2	26.6	10	8.3	8.7	4.7	2.9	
	Medium: In separate place	57.8	52.1	62.2	24.3	38.2	31.1	24.7	
	High: Built-in housing		21.3	27.7	67.4	53.2	64.2	72.4	
Roof quality	Low: Thatched or similar material	27.1	27.9	11	5.7	2.4	0.8	0.9	
	Medium: Tile, metal	72.9	72.1	89	94.3	94.1	78.5	78.8	
	High: Concrete, duralite					3.4	20.7	20.3	
Sewage facility	Low: No drain	98.9	99.2	99.7	99.1	89.3	46	45.3	
	Medium: Cesspit system	1.1	0.8	0.2	0.8		2	0.2	

	High: Sewage system, septic tank			0.2	0.2	10.7	52	54.5	
Stove quality	Low: None, on floor	98.5	94.7	96.3	53.2	45.6	32.2	26.6	
	Medium: Low or high removable/fixed wood and charcoal stove	1.5		1.5	43.7	54.4	66.7	72.3	
	High: Gas or electric stove		5.3	2.3	3.1		1.1	1.1	
Toilet quality	Low: None	94.5	94.2	100	97.5	81	20	23.4	
	Medium: Latrine, pit latrine	5.5	5.8		2.5	12.4	22.9	19.3	
	High: Septic tank + indoor toilet					6.6	57.1	57.3	
Wall quality	Low: Cane or similar, mix of clay, cane and wood (with or without cement)	54.3	43.7	18.6	12.6	7.4	4.6	2.3	
	Medium: Mud brick with or without cement, wood, metal	45.7	56.3	72.6	68.2	52.9	24.2	20.3	
	High: Brick			8.8	19.2	39.6	71.3	77.5	
Source of water quality	Low: Spring or river	51.9	18.1	3.1	1.2		2.1	2.2	
	Medium: Public pool with pitchers, well in neighborhood or house	48.1	81.9	63.7	8.6	4.3	6	9.1	
	High: Public water system			33.2	90.2	95.7	91.8	88.7	
Land ownership	Yes, No		73.5	80.4	72.8	53.1	72.9	67.1	
Birds	Yes, No			64.5	62	57.2	41.9	28.6	
Pigs	Yes, No			48.5	29.7	25.2	9	7.9	
Turntable	Yes, No		2.4	6	12.6				

Hand grinder	Yes, No			8.1	7.2	4.8			
Electric iron	Yes, No			32.9	79.5	83.9			
Cassette player	Yes, No				55.2	38.2			
Sound system	Yes, No					37.9	59	57.5	
Video player	Yes, No				4.5	8.7	55.2	47.5	
Cable	Yes, No					5	63.6	67.4	
Blender	Yes, No					41.2	77.2	82.6	
Typewriter	Yes, No					9.9			
Garbage disposal quality	Low: Throw in yard						1.5	0.8	
	Medium: Bury, burn or throw in ravine						50	50.4	
	High: Public dump						48.5	48.7	
Microwave	Yes, No					2.4	32.8	32.8	
Computer	Yes, No					1.3	34.3	30.4	
Cellphone	Yes, No						94.9	95.3	
Ipod	Yes, No						10.1	12.8	
Washing machine	Yes, No						18.7	20.7	
Internet	Yes, No							13.2	
Direct TV	Yes, No							5.3	

Supplementary Table 4.3 Categorization and availability of assets for New Delhi Birth Cohort by study wave

	Survey Year								
	Percentage of original sample with asset data	74.6%	18.7%	14.0%	9.7%	10.3%			
Asset	**Categorization**	**1969-72**	**1998-02**	**2006-09**	**2012-16**	**2016-19**			
Air conditioner	Yes, No		29.6	50.8	72.2	80.9			
Bed	Yes, No					99.9			
Bicycle	Yes, No		28.1	58.6	56	50.3			
Cable TV	Yes, No		93.1	87.5	55.6				
Car	Yes, No		45.1	59.7	68.8	69.9			
Cellphone	Yes, No			95.7	99.6	99.3			
Chair	Yes, No					99.8			
Clock	Yes, No					100			
Computer	Yes, No		17.6	45.6	78	79.5			
Cooler	Yes, No		91.2	85.3	61.7	48.5			
Dish TV	Yes, No		1.4	14.6	56.5				
Electricity	Yes, No		99.9	100	100	99.9			
Fan	Yes, No		100	99.8	99.9	100			
Internet	Yes, No					77.1			
Mattress	Yes, No					100			
Mixer grinder	Yes, No		90.8	94.4	95.2				
Owns house	Yes, No					97.6			
Pressure cooker	Yes, No					99.9			
Radio	Yes, No		88.7	80.7	49.4	44.4			
Refrigerator	Yes, No					99			
Separate kitchen	Yes, No					98.9			
Sewing machine	Yes, No					61.1			
Stove	Yes, No		98.6	99.1	99.5				

Table	Yes, No					99.6			
Telephone	Yes, No		86.2	73.2	48.7	48.9			
Television (any)	Yes, No		99.6	99.3	99.2	98.9			
Television – black & white	Yes, No					2.3			
Television – color	Yes, No					77.7			
Television – plasma	Yes, No					76.1			
Tractor	Yes, No					0.5			
Two wheeler	Yes, No		81.4	77.7	77	74.8			
Washing machine	Yes, No		79.2	89.4	94.1				
Water pump	Yes, No					77.8			
Drinking water	Low: Unprotected, Open well/river			1.6	0.1	0.2			
	Medium: Both protected and unprotected, borewell or handpump		6	3.4	7.8				
	High: Protected, tap, mineral water, tanker water		94	95	92	99.8			
Sharing of drinking water	Low: Communal	17.7	0.7	0.1	1.6				
	Medium: Common	47.8	10.3	5.7	20.4				
	High: Separate, mineral water, tanker water	34.4	88.9	94.2	78				
General water supply	Low: Unprotected, Open well/river			0.9					

	Medium: Both protected and unprotected, borewell or handpump		14.5	5.2	17.2				
	High: Protected, tap, mineral water, tanker water		85.5	93.9	82.8				
Sharing of general water	Low: Communal		0.4	0.2	1.4				
	Medium: Common		6.7	10.5	28.5				
	High: Separate, mineral water, tanker water		92.9	89.3	70.1				
Type of house	Low: Thatched hut	1.8							
	Medium: Masonry built	67.2	0.2	0.4	0.1				
	High: Flats, Bungalow, Other	31	99.8	99.6	99.9				
Type of lighting	Low: Oil								
	Medium: Kerosene, gas					0.1			
	High: Electricity					99.9			
Type of toilet	Low: Open field		0.7		0.1	0.2			
	Medium: 1969-72: Pit, scavenger cleaned		10.3	3.7	3.3	0.4			
	High: Flush		89	96.3	96.6	99.4			
Sharing of toilet	Low: Communal	22.7				99.3			
	Medium: Common	39.8				0.7			
	High: Separate	37.5							

Supplementary Table 4.4 Categorization and availability of assets for Cebu Longitudinal Health and Nutrition Study by study wave

	Survey Year								
	Percentage of original sample with asset data	100%	72.7%	71.1%	67.8%	65.6%	61.3%	55.6%	43.1%
Asset	**Categorization**	**1983**	**1991**	**1994**	**1998**	**2002**	**2005**	**2009**	**2018**
Air conditioning	Yes, No	0.3	0.7	1.0	2.8	4.4	6.7	9.9	19.7
Bicycle	Yes, No	14.5	17.8	23	25.7	29.3	29.4	23.8	29.1
Car	Yes, No	0.8	1.5	2.3	3.4	3.1	4.2	4.4	9.5
Chicken/poultry	Yes, No	42.8	49.3	50	46.5	50.5	42.2	-	39.2
Electric fan	Yes, No	14.3	37.5	45.8	59.4		73.2	78.3	88.3
Electric iron	Yes, No	9.8	28.9	37.9	50.9	58	58.1	56.6	60.9
Electricity	Yes, No		73.8	80.1	87.2	91.8	94.4	95	96.1
Jepny	Yes, No	0.9	1.7	2.2	3	5.2	6.6	6.5	6.8
Living room set	Yes, No	27	41	42.8	47.1	52.4	52.4	-	46.6
Other appliances	Yes, No	2.8	8.9	50.3	65.9	22.3	6	4.7	-
House	Yes, No	65.9	84	86.5	88.5	87	84.4	78.5	80
Refrigerator	Yes, No	6.7	21.7	28.5	37	41.3	42.3	42.1	47.2
Cleanliness of are where food is stored	Low: Filthy	8.8	15.6	6.7	20.3	14.3	7.2	8	14.2
	Medium: Not so clean	72.8	61.7	75.7	68.3	63.5	69.5	68.5	49.3
	High: Very clean	18.5	22.7	17.6	11.5	22.2	23.3	23.5	36.5
Cooking fuel	Low: Wood/charcoal, sawdust, other	83.9	61.8	47.5	33.6	36.1	44.7	60.5	17.1
	Medium: Kerosene, combination of fuels	10	22.1	29.8	29.4	18.9	17.3	5	0.2
	High: Electricity, LPG	6.1	16.1	22.7	36.9	45	38	34.5	82.7
Garbage disposal	Low: Dumped around/near house, in	42.5	47.3	48.5	55.7	10.5	9.5	14.2	6.3

	stream or river, combination of methods, Dumped away from house								
	Medium: Burning, other	41	52.7	51.5	44.3	35.6	35.7	21.4	16.2
	High: Collected by garbage collector, composting	16.5				53.9	54.8	64.4	77.5
Condition of area for excreta	Low: Heavy defecation in area	6.5	11.8	6.4	20.6	11.6	5.5	3.6	1.7
	Medium: Some defecation or very little defecation in area	43.9	57.6	78.2	73	63.4	69.1	57.6	35.2
	High: No excreta visible	49.5	30.6	15.4	6.5	25.1	25.4	38.8	63.1
Lighting	Low: Oil, Candle	0.1		0	0	0.1	0.3	0.1	0.4
	Medium: Kerosene, Other material	50.1	26.5	19.9	13.9	9.1	7	6.4	4.9
	High: Electricity, LPG	49.7	73.5	80	86	90.7	92.8	93.6	94.7
Housing material	Low: Wood or similar	43	40.2	38	25.9	23.1	23.5	19.7	30.9
	Medium: Cement and/or wood mixed with similar roofing	38.9	39.2	50.1	60.7	49.6	56.1	54.7	39.3
	High: Cement or wood with galvanized iron roofing	18.1	20.6	11.9	13.4	27.3	20.4	25.6	29.8
Neighborhood excreta removal	Low: Heavy defecation in area	-	10.9	7	18.6	12	6.3	4.3	4.4
	Medium: Some defecation or very little defecation in area	-	64.8	85	77.6	71.8	73.4	67.5	44.6
	High: No excreta visible	-	24.2	7.9	3.8	16.2	20.3	28.2	50.9

Neighborhood garbage removal	Low: Lots of uncollected garbate	-	12.6	5.1	15.2	11.6	6.4	5.1	14.3
	Medium: Some or very little garbage	-	80.7	91.1	83.7	82.1	85.6	77.4	46.8
	High: No garbage visible	-	6.6	3.8	1.1	6.3	8	17.5	38.9
Drinking water	Low: Spring, river, rainwater	6.6	8.9	8.7	10	8.2	6.9	27.3	4.4
	Medium: Dug well without pump, open well	80.1	12.7	46	29.7	16.3	20.4	10.6	0.2
	High: Metro or other piped supply, Tubewell/motorized pump, purchased mineral/bottled water	13.4	78.3	45.3	60.3	75.5	72.8	62.1	95.4
Toilet	Low: None or other	28.8	33.5	28	22.9	18.5	14.7	11.3	5.2
	Medium: Latrine, open pit	31.4	9.3	7.2	4.2	2.9	3	1.3	0.9
	High: Flush toilet (inside or outside), water-sealed toilet (inside or outside)	39.8	57.2	64.7	72.9	78.6	82.3	87.3	93.9
Beds	Yes, No	38.8	43	51.8	65.5	68.6	71.7	-	71.3
Boat	Yes, No	0.3		2	2.3	1.2	0.8	1	0.8
Cattle (cows or carabaos)	Yes, No	5.7	7.9	8	6.7	6	4.5	-	3
Farm animals (goat, horse, pig etc)	Yes, No	36.7	33.1	24.7	18.1	20.2	15.8	-	7.9
Other vehicles (banca,	Yes, No	5.3	3.4	0.6	2.3	8.3	8.2	7.9	8

motorcycle or tricycle with side-car etc)									
Truck or bus	Yes, No	0.1	0.3	0.4	0.9	0.7	0.7	0.8	0.8
Television	Yes, No	18.2	53.7	61.9	70.8	62.4	72.9	78	76.6
Drinking water storage	Low: Open drum, can (tin)	1.6							
	Medium: Earthern jar or plastic container without faucet	65							
	High: Container in fridge, water tank, earthern jar or plastic container with faucet	33.4							
Beautician kit	Yes, No	8.9							
Benches or chairs	Yes, No	68.6	74.8						
Bottle brush	Yes, No	23.7							
Chest/closet of drawers	Yes, No	68.1	58.3	61.3	67.2				
Clay pots/ pan	Yes, No	75.6							
Clay stove	Yes, No	53.9							
Dining set	Yes, No	13.2	15.1			59.1	67.6		51.8
Feeding bottles	Yes, No	44.8							
Flat iron	Yes, No	42.9							
Glassware	Yes, No	41							
Kerosene stove	Yes, No	16.9				32.2	27.2	10.9	3.2
Measuring spoon	Yes, No	8.4							
Other business machine	Yes, No	6.5							
Other kitchen equipment	Yes, No	67.7							

Other agricultural equipment	Yes, No	20.7							
Radio	Yes, No	55.8							
Sewing machine	Yes, No	12.5				20.1	17.5	14.8	9.7
Tables	Yes, No	69.9	76.7						
Tape recorder/ stereo set	Yes, No	18.8	44.1				35.6	34.4	15.6
Thermos bottle	Yes, No	56.3							
Other house	Yes, No	7.9							
Gas stove	Yes, No	12.3				38.9	38.9	44.5	80
Other furniture	Yes, No	0.6	8.7	19.3	84.5	27	5.2		
Electricity in neighborhood	Yes, No		87.7	91.9	94.3	97.8	98.9		99.4
Neighborhood construction material	Low: Light (bamboo, nipa, cheap wood)			39.9	20	21.4	20.3	16.3	18.6
	Medium: Mixed (wood with hollow blocks, cement)			54.5	74.8	61.9	63.1	63.2	62.6
	High: Strong (hollow blocks, concrete or good wood)			5.6	5.2	16.7	16.6	20.5	18.8
China cabinet	Yes, No			7.9	14.9	75.9	75.5		73.7
Motorcycle	Yes, No			5.2	8.4	12.2	16.3	26.1	49.2
Digital camera	Yes, No			16.2	27.7	40.1	11.6	19.1	18.5
Phone	Yes, No			6.4	18	40.4	68	40.7	93.3
House is neat	Low: Poorly kept, dirty or messy				21.6	16.7	10.5	9.7	20.1
	Medium: Not so neat				66.7	63	68	69.2	44.2
	High: Neat and tidy				11.7	20.3	21.5	21.1	35.7
Cable + TV	Yes, No					6.9	6.7	5.4	12.4

CD player	Yes, No					18.8	31.2	46.7	59.2
Karaoke machine	Yes, No					45.3	45.9	42.6	46.6
Oven	Yes, No					17.6	14.7	12.3	11
Pressure cooker	Yes, No					15.7	16.3	15.8	26.9
Rice cooker	Yes, No					22	29.9	44.7	54.4
VCR player	Yes, No					41.9	51	68.1	
Washing machine	Yes, No					20.5	22.8	23.7	37.5
Computer	Yes, No					5.1	11.1	19.7	27.7
Microwave	Yes, No					3.5	6	11.7	
Video game	Yes, No						8.2	9.1	6.9
Non-drinking water source	Low: Spring, River, Rainwater								8.2
	Medium: Dug well without pump								15
	High: Piped supply (Metro, other), Tubewell or borehole or motorized pump								76.8
Vacuum cleaner	Yes, No	0.1				2.4	2.7	3.8	6.4
Tablet	Yes, No								32.7
Electric water dispenser	Yes, No								14.1

Supplementary Table 4.5 Categorization and availability of assets for Birth to Twenty plus cohort by study wave

	Survey Year								
	Percentage of original sample with asset data	85.9%	41.1%	44.1%	46.2%	50.0%	42.6%		
Asset	**Categorization**	**1990-92**	**1997-98**	**2002-03**	**2006-07**	**2012-13**	**2017-18**		
Car	Yes, No	32.4	27	28.5	32.4	42.3	44		
Electricity	Yes, No	92.1	97.2	96.9	97.5	95.8			
Microwave	Yes, No		16.7	38.1	58.8	82	83.2		
Radio	Yes, No	84.5	87.9	86.9	87.9	88.1			
Refrigerator	Yes, No	70.4	87.4	91	93.6	93.2	92.7		
Telephone	Yes, No	53.5	51.5	50.5	40.4	25.8	42.4		
Television	Yes, No	73.7	92.1	92.1	95.4	94.6	92.4		
Washing machine	Yes, No	20.1	26.9	33.4	46.5	66.9	72.1		
Indoor flush toilet	Yes, No	36.9	38.5	49.5	54.1		73.5		
Indoor hot or cold water	Yes, No	54.9	55.7	67.7	75.0		78.6		
Housing type	Low: Shack		6.3	8.4			6.6		
	Medium: Room, Shared house, Hostel, Garage	17.9	5.5	6.1			11.6		
	High: House, Flat	82.1	88.2	85.5			81.8		
Refuse disposal	Low: Leave in the street, other								
	Medium: Communal heap, own refuse heap								
	High: Own garbage bin								
House ownership	Yes, No	25.2	27.2				78.5		
Solo usage of water	Yes, No	76.6		76.1	70.9				

Solo usage of toilet	Yes, No	74.8		87	46.4				
DVD player	Yes, No		30	39.9	68.1	86.1			
Cellphone	Yes, No			58.9	91.4	95.1	88.4		
Mnet	Yes, No			4.2	6.7				
Satellite TV	Yes, No			3.1	7.2				
Computer	Yes, No				21.8	58	57.6		
Internet	Yes, No				4	57.5	53.4		

Supplementary Table 4.6 Comparison of early life characteristics for Pelotas 1993 cohort for non-participants in study wave

	Original	Not available or Died							
	1993	**1997**	**2004**	**2008**	**2011**	**2015**			
N	**5249**	**3976**	**822**	**909**	**1142**	**1438**			
Maternal age	26.0±6.4	25.9±6.4	25.8±6.4	25.6±6.4	25.7±6.5	25.9±6.5			
Paternal age	29.5±7.7	29.5±7.8	29.2±7.4	29.3±7.5	29.2±7.6	29.4±7.8			
Maternal education	6.7±3.6	6.8±3.6	7.1±4.0	6.8±3.9	6.6±3.9	6.4±3.7			
Paternal education	6.8±3.5	6.9±3.6	7.2±3.9	7.0±3.9	6.9±3.8	6.6±3.6			
Mother employed during pregnancy									
Yes	1911 (36.4%)	1447 (36.4%)	302 (36.8%)	316 (34.8%)	382 (33.5%)	478 (33.3%)			
No	3229 (61.6%)	2453 (61.7%)	496 (60.5%)	567 (62.5%)	737 (64.6%)	934 (65.0%)			
Student	73 (1.4%)	55 (1.4%)	17 (2.1%)	20 (2.2%)	18 (1.6%)	16 (1.1%)			
Stay at home	31 (0.6%)	18 (0.5%)	5 (0.6%)	4 (0.4%)	4 (0.4%)	8 (0.6%)			
Maternal skin color									
White	4058 (77.4%)	3081 (77.5%)	653 (79.4%)	725 (79.8%)	903 (79.1%)	1148 (79.8%)			
Black	954 (18.2%)	724 (18.2%)	140 (17.0%)	151 (16.6%)	191 (16.7%)	234 (16.3%)			
Other	234 (4.5%)	169 (4.3%)	29 (3.5%)	33 (3.6%)	48 (4.2%)	56 (3.9%)			
Sex									
Female	2645 (50.4%)	1981 (49.8%)	399 (48.5%)	431 (47.4%)	554 (48.5%)	618 (43.0%)			
Male	2603 (49.6%)	1995 (50.2%)	423 (51.5%)	478 (52.6%)	588 (51.5%)	820 (57.0%)			
Skin color of index child									
White	2769 (64.1%)	2062 (64.6%)	68 (70.1%)	3 (60.0%)	243 (62.5%)	507 (67.7%)			

Black	611 (14.1%)	437 (13.7%)	6 (6.2%)	0 (0.0%)	43 (11.1%)	73 (9.7%)			
Other	943 (21.8%)	692 (21.7%)	23 (23.7%)	2 (40.0%)	103 (26.5%)	169 (22.6%)			

Supplementary Table 4.7 Comparison of early life characteristics for INCAP Longitudinal Study cohort for participants in study wave

		Not available or Died					
	Original	**1987**	**1996**	**2002**	**2015-16**	**2017-18**	
N	2392	1032	1539	1339	1229	1127	
Maternal age at birth of index child	27.0±7.2	26.4±7.2	26.4±7.2	26.5±7.2	27.0±7.3	27.0±7.4	
Maternal height (cm)	148.7±5.2	148.4±5.4	148.7±5.2	148.7±5.2	148.9±5.4	149.0±5.4	
Maternal schooling	1.0 [0.0;2.0]	0.0 [0.0;2.0]	1.0 [0.0;2.0]	1.0 [0.0;2.0]	1.0 [0.0;2.0]	1.0 [0.0;2.0]	
Birth year (19XX)	71 [67;74]	69 [66;72]	71 [67;73]	71 [67;74]	71 [67;74]	71 [67;74]	
Type of nutritional supplementation							
Fresco supplementation	1123 (46.9%)	470 (45.5%)	681 (44.2%)	602 (45.0%)	592 (48.2%)	525 (46.6%)	
Atole supplementation	1269 (53.1%)	562 (54.5%)	858 (55.8%)	737 (55.0%)	637 (51.8%)	602 (53.4%)	
Sex							
Male	1230 (51.4%)	471 (45.6%)	787 (51.1%)	670 (50.0%)	766 (62.3%)	668 (59.3%)	
Female	1162 (48.6%)	561 (54.4%)	752 (48.9%)	669 (50.0%)	463 (37.7%)	459 (40.7%)	

Supplementary Table 4.8 Comparison of early life characteristics for New Delhi Birth Cohort for participants in study wave

		Not available or Died						
	Original	**1969-72**	**1998-02**	**2006-09**	**2012-16**	**2016-19**		
N	8181	2068	6643	7030	7383	7335		
Maternal age at birth of index child	25.9±5.2	29.3±0.6	25.7±5.1	25.8±5.1	25.8±5.2	25.8±5.2		
Maternal schooling	3.0 [0.0;10.0]	10.0 [3.0;12.0]	3.0 [0.0;10.0]	3.0 [0.0;10.0]	3.0 [0.0;10.0]	3.0 [0.0;10.0]		
paternal education	12.0 [8.0;15.0]	12.0 [12.0;15.0]	12.0 [8.0;13.5]	12.0 [8.0;15.0]	12.0 [8.0;15.0]	12.0 [8.0;15.0]		
year of birth	1971.0 [1970.0;1972.0]	1971.0 [1970.0;1972.0]	1971.0 [1970.0;1972.0]	1971.0 [1970.0;1972.0]	1971.0 [1970.0;1972.0]	1971.0 [1970.0;1972.0]		
Sex								
Male	3924 (48.0%)	1074 (51.9%)	3036 (45.7%)	3265 (46.4%)	3436 (46.5%)	3405 (46.4%)		
Female	3606 (44.1%)	991 (47.9%)	2966 (44.6%)	3134 (44.6%)	3315 (44.9%)	3299 (45.0%)		
'Missing'	641 (7.8%)	3 (0.1%)	641 (9.6%)	631 (9.0%)	632 (8.6%)	631 (8.6%)		
Religion								
Hindu	5172 (63.3%)	6 (0.3%)	4263 (64.2%)	4491 (63.9%)	4709 (63.8%)	4676 (63.7%)		
Muslim	81 (1.0%)	0 (0.0%)	80 (1.2%)	80 (1.1%)	81 (1.1%)	81 (1.1%)		
Sikh	651 (8.0%)	0 (0.0%)	523 (7.9%)	550 (7.8%)	586 (7.9%)	589 (8.0%)		
Jain	47 (0.6%)	0 (0.0%)	32 (0.5%)	37 (0.5%)	36 (0.5%)	36 (0.5%)		
Christian	142 (1.7%)	0 (0.0%)	138 (2.1%)	140 (2.0%)	140 (1.9%)	141 (1.9%)		
Others	12 (0.1%)	0 (0.0%)	12 (0.2%)	12 (0.2%)	12 (0.2%)	11 (0.1%)		
'Missing'	2066 (25.3%)	2062 (99.7%)	1595 (24.0%)	1720 (24.5%)	1819 (24.6%)	1801 (24.6%)		

Supplementary Table 4.9 Comparison of early life characteristics for Cebu Longitudinal Health and Nutrition Study for participants in study waves

		Not available or Died						
Categorization	**Original**	**1991**	**1994**	**1998**	**2002**	**2005**	**2009**	**2018**
N	3080	816	894	998	1065	1194	1371	1754
Maternal age at birth of index child	26.3±6.0	26.2±5.8	26.2±5.9	26.2±6.0	26.2±6.0	26.2±6.0	26.1±6.0	26.1±5.9
Maternal schooling (y)	6.0 [5.0;9.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]	6.0 [5.0;10.0]
Maternal height (cm)	150.6±5.0	150.5±5.0	150.5±5.0	150.5±5.0	150.5±5.1	150.6±5.0	150.7±5.0	150.8±5.1
Sex								
Male	1632 (53.0%)	437 (53.6%)	487 (54.5%)	545 (54.6%)	564 (53.0%)	640 (53.6%)	739 (53.9%)	917 (52.3%)
Female	1448 (47.0%)	379 (46.4%)	407 (45.5%)	453 (45.4%)	501 (47.0%)	554 (46.4%)	632 (46.1%)	837 (47.7%)

Supplementary Table 4.10 Comparison of early life characteristics for Birth to Twenty plus cohort for participants in study waves

		Not available or Died						
Categorization	**Original**	**1997-98**	**2002-03**	**2006-07**	**2012-13**	**2017-18**		
N	3273	1928	1831	1762	1650	1879		
Maternal age (y)	26.0±6.1	26.2±6.0	26.0±5.9	26.1±5.9	26.1±5.9	26.1±5.9		
Maternal schooling	9.0 [9.0;11.5]	9.0 [9.0;11.5]	9.0 [9.0;11.5]	9.0 [9.0;11.5]	9.0 [9.0;11.5]	9.0 [9.0;11.5]		
Paternal schooling	11.5 [9.0;11.5]	11.5 [9.0;14.0]	11.5 [9.0;14.0]	11.5 [9.0;14.0]	11.5 [9.0;14.0]	11.5 [9.0;14.0]		
Ethnicity								
White	207 (6.3%)	205 (10.6%)	206 (11.3%)	204 (11.6%)	204 (12.4%)	205 (10.9%)		
Black	2568 (78.5%)	1354 (70.2%)	1229 (67.1%)	1198 (68.0%)	1096 (66.4%)	1335 (71.0%)		
Colored	383 (11.7%)	266 (13.8%)	289 (15.8%)	257 (14.6%)	248 (15.0%)	233 (12.4%)		
Indian	115 (3.5%)	103 (5.3%)	107 (5.8%)	103 (5.8%)	102 (6.2%)	106 (5.6%)		
Sex								
Male	1591 (48.6%)	943 (48.9%)	902 (49.3%)	864 (49.0%)	812 (49.2%)	931 (49.5%)		
Female	1682 (51.4%)	985 (51.1%)	929 (50.7%)	898 (51.0%)	838 (50.8%)	948 (50.5%)		

Supplementary Table 4.11 Loadings of harmonized index and cross-sectional indices with all assets for Pelotas 1993 cohort

	Survey Year	**Harmonized**	**1997**	**2004**	**2008**	**2011**	**2015**			
	Variance explained by PC1 (%)	44.6%	55.7%	50.2%	43.2%	42.3%	30.6%			
	Correlation with harmonized	1.00	0.94	0.95	0.96	0.94	0.78			
Asset	**Categorization**									
Rooms per person	Crowding	0.32		0.55	0.46	0.36	0.08			
Car	Yes, No	0.74	0.8	0.81	0.77	0.75	0.67			
Computer	Yes, No	0.81		0.86	0.83	0.8	0.73			
Duplex refrigerator	Yes, No	0.67		0.75	0.67	0.59	0.65			
DVD player	Yes, No	0.77	0.85	0.82	0.72	0.63	0.22			
Housekeeper	Yes, No	0.63	0.74	0.77	0.82	0.81				
Radio	Yes, No	-0.19	0.64	0.47	0.4		0.26			
Refrigerator	Yes, No	0.54	0.79	0.67	0.57		-0.24			
Television	Yes, No	0.84	0.85	0.77						
Vacuum cleaner	Yes, No	0.77	0.82	0.83	0.81	0.77				
Washing machine	Yes, No	0.77	0.8	0.78	0.77	0.69	0.74			
Piped water	Low, Medium, High	0.62								
Housing material	Low, Medium, High		0.66	0.66						
Toilet	Low, Medium, High		0.78							
Motorcycle	Yes, No		0.32				0.07			
Stereo	Yes, No			0.7	0.67					
House ownership	Yes, No			0.14	0.13	0.23				
Video game	Yes, No				0.54	0.42				

Air conditioning	Yes, No					0.76	0.83			
Desktop	Yes, No					0.64				
Notebook computer	Yes, No					0.68				
Microwave	Yes, No					0.67	0.65			
Cleaning lady	Yes, No						0.72			
Clothes dryer	Yes, No						0.63			
Street is paved	Yes, No						0.35			

Supplementary Table 4.12 Loadings for harmonized index and cross-sectional indices with all assets for INCAP Longitudinal Study

	Survey Year	**Harmonized**	**1967[1]**	**1975**	**1987**	**1996**	**2002**	**2015-16**	**2017-18**	
	Variance explained by PC1 (%)	54.4%	44.0%	32.5%	33.5%	30.3%	29.2%	33.6%	34.2%	
	Correlation with harmonized	1.00	0.95	0.89	0.81	0.82	0.87	0.94	0.92	
Asset	**Categorization**									
Crowding	Number of rooms/person	0.44	0.38	0.24	0.02	0.12	0.25	0.34	0.31	
Bicycle	Yes, No	0.59			0.55	0.45	0.47	0.26	0.18	
Car	Yes, No	0.81					0.63	0.74	0.74	
Electricity	Yes, No	0.94		-0.08	0.69	0.52				
Motorcycle	Yes, No	0.72						0.46	0.41	
House ownership	Yes, No	0.09	0.07	0.29	0.57	0.51	0.43	0.07	0.11	
Radio	Yes, No	-0.17	0.4	0.55	0.68	0.79	0.04	0	-0.01	
Refrigerator	Yes, No	0.9				0.72	0.86	0.82	0.78	
Sewing machine	Yes, No	0.46		0.78	0.6	0.6	0.62	0.49	0.45	
Television	Yes, No	0.94			0.86	0.76	0.69	0.76	0.83	
Floor quality	Low, Medium, High	0.87		0.56	0.68	0.63	0.59	0.68	0.73	
Kitchen location	Low, Medium, High	0.68	0.75	0.69	0.33	0.17	0.33	0.55	0.51	
Roof quality	Low, Medium, High	0.82	0.88	0.8	0.6	0.44		0.75	0.75	
Sewage facility	Low, Medium, High	0.81					0.37	0.57	0.5	
Stove quality	Low, Medium, High	0.84		0.78		0.63		0.81	0.82	
Toilet quality	Low, Medium, High	0.80	0.63	0.19			0.45	0.41	0.37	
Wall quality	Low, Medium, High	0.85	0.97	0.85	0.64	0.44	0.44	0.45	0.66	
Source of water quality	Low, Medium, High	0.81	0.74	0.55	0.29	0.4		0.32	0.17	

Land ownership	Yes, No			0.27	0.57	0.48				
Birds	Yes, No				0.27	0.4	0.22	-0.23	-0.15	
Pigs	Yes, No				0.27	0.25	0.13	-0.19	-0.1	
Turntable	Yes, No				0.78	0.68				
Hand grinder	Yes, No				0.49	0.31				
Electric iron	Yes, No				0.78	0.79	0.78			
Cassette player	Yes, No					0.74	0.15			
Sound system	Yes, No						0.72	0.54	0.49	
Video player	Yes, No						0.79	0.6	0.57	
Cable	Yes, No						0.36	0.69	0.57	
Blender	Yes, No						0.75	0.73	0.69	
Typewriter	Yes, No						0.68			
Garbage disposal quality	Low, Medium, High							0.59		
Microwave	Yes, No							0.75	0.73	
Computer	Yes, No							0.78	0.77	
Cellphone	Yes, No							0.52		
Ipod	Yes, No							0.53	0.68	
Washing machine	Yes, No							0.83	0.79	
Internet	Yes, No								0.84	
Direct TV	Yes, No								0.61	

1 Quality of roof, wall, kitchen, toilet and source of water were converted into binary variables (low vs medium) for 1967 due to absence of any values in 'High' category.

Supplementary Table 4.13 Loadings for harmonized index and cross-sectional indices with all assets for New Delhi Birth Cohort

	Survey Year	**Harmonized**	**1998-02**	**2006-09**	**2012-16**	**2016-19**				
	Variance explained by PC1 (%)	26.5%	33.5%	31.8%	25.3%	34.7%				
	Correlation with harmonized	1.00	0.85	0.93	0.91	0.75				
Asset	**Categorization**									
Crowding	Number of rooms per person	0.29	0.39	0.41	0.4	0.31				
Air conditioner	Yes, No	0.89	0.68	0.85	0.87	0.92				
Bicycle	Yes, No	0.35	-0.1	0.44	0.28	0.3				
Cable TV	Yes, No	-0.44	0.75	-0.08	-0.34					
Car	Yes, No	0.75	0.76	0.85	0.85	0.84				
Cellphone	Yes, No	0.81								
Computer	Yes, No	0.89	0.62	0.81	0.82	0.89				
Cooler	Yes, No	-0.53	0.36	-0.06	-0.5	-0.5				
Dish TV	Yes, No	0.83		0.61	0.51					
Mixer grinder	Yes, No	0.57	0.84	0.85						
Radio	Yes, No	-0.24	0.49	0.45	0.35	0.28				
Telephone	Yes, No	0.01	0.82	0.66	0.71	0.53				
Television	Yes, No	0.02								
Two wheeler	Yes, No	0.03	0.52	0.2	0.09	0.04				
Washing machine	Yes, No	0.66	0.76	0.73	0.63					
Drinking water source	Low, Medium, High	0.12	0.3		-0.02					
Sharing of drinking water	Low, Medium, High	-0.01	0.41	0.32	0.07					
General water	Low, Medium, High	0.07	0.19	0.39	0.00					
Sharing of general water	Low, Medium, High	-0.14	0.55	0.28	0.00					

Sharing of toilet	Low, Medium, High	0.53	0.59							
Television-color	Yes, No					-0.44				
Water pump	Yes, No					-0.27				
Sewing machine	Yes, No					-0.20				
Internet	Yes, No					0.90				
Television - plasma	Yes, No					0.78				

Supplementary Table 4.14 Loadings for harmonized index and cross-sectional indices with all assets for Cebu Longitudinal Health and Nutrition Study

	Survey Year	**Harmonized**	**1983**	**1991**	**1994**	**1998**	**2002**	**2005**	**2009**	**2018**
	Variance explained by PC1 (%)	35.5%	29.7%	40.1%	40.7%	39.8%	33.5%	36.2%	42.9%	34.5%
	Correlation with harmonized	1.00	0.92	0.99	0.98	0.98	0.96	0.96	0.93	0.94
Asset	**Categorization**									
Number of rooms per person	Crowding	0.33	0.23	0.46	0.5	0.43	0.38	0.41		0.26
Air conditioning	Yes, No	0.8						0.85	0.89	0.87
Bicycle	Yes, No	0.36	0.32	0.4	0.39	0.34	0.32	0.26	0.23	0.28
Car	Yes, No	0.81								0.85
Chicken/poultry	Yes, No	-0.18	-0.11	-0.27	-0.24	-0.23	-0.18	-0.14		-0.1
Electric fan	Yes, No	0.78	0.9	0.9	0.88	0.86		0.8	0.82	0.65
Electric iron	Yes, No	0.87	0.84	0.86	0.84	0.83	0.82	0.8	0.79	0.79
Electricity	Yes, No	0.83		0.91		0.89	0.73	0.79	0.86	
Jepny	Yes, No	0.65					0.62	0.62	0.69	0.52
Living room set	Yes, No	0.71	0.82	0.76	0.75	0.72	0.76	0.78		0.74
Other appliances	Yes, No	0.38		0.76	0.72	0.71	0.11	0.34		
House	Yes, No	0.09	-0.1	-0.17	-0.15	-0.08	0.04	0.16	0.1	0.14
Refrigerator	Yes, No	0.88	0.92	0.88	0.87	0.88	0.85	0.85	0.85	0.83
Cleanliness of are where food is stored	Low, Medium, High	0.49	0.47	0.59	0.62	0.55	0.56	0.55	0.6	0.61
Cooking fuel	Low, Medium, High	0.82	0.67	0.8	0.83	0.82	0.82	0.78	0.8	0.61
Garbage disposal	Low, Medium, High	0.36	0.3	-0.07	-0.3	-0.38	0.42	0.41	0.45	0.33

Condition of area for excreta	Low, Medium, High	0.25	0.31	0.35	0.39	0.37	0.35	0.31	0.33	0.39
Lighting	Low, Medium, High	0.91	0.83	0.92		0.87	0.76	0.7	0.96	
Housing material	Low, Medium, High	0.66	0.7	0.7	0.75	0.7	0.67	0.7	0.74	0.73
Neighborhood excreta removal	Low, Medium, High	0.56		0.27	0.33	0.32	0.25	0.27	0.27	0.38
Neighborhood garbage removal	Low, Medium, High	0.61		0.42	0.38	0.46	0.39	0.27	0.38	0.42
Drinking water	Low, Medium, High	0.53	0.69	0.55	0.51	0.53	0.44	0.46	-0.03	
Toilet	Low, Medium, High	0.79	0.68	0.77	0.78	0.77	0.74	0.72	0.79	0.84
Beds	Yes, No	0.7	0.74	0.68	0.7	0.65	0.62	0.68		0.56
Boat	Yes, No	-0.02								
Cattle (cows or carabaos)	Yes, No	-0.32	-0.29	-0.38	-0.37	-0.43	-0.24			
Farm animals (goat, horse, pig etc)	Yes, No	-0.31	-0.06	-0.3	-0.26	-0.23	-0.09	-0.14		0.01
Other vehicles (banca, motorcycle or tricycle with side-car etc)	Yes, No	0.18	0.22				0.11	0.1	0.09	-0.09
Truck or bus	Yes, No	0.52								
Television	Yes, No	0.75	0.89	0.89	0.82	0.8	0.53	0.46	0.51	0.12
Drinking water storage	Low, Medium, High		0.37							
Beautician kit	Yes, No		0.43							
Benches or chairs	Yes, No		0.48	0.24						
Bottle brush	Yes, No		0.53							

Chest/closet of drawers	Yes, No		0.45	0.67	0.63	0.55				
Clay pots/ pan	Yes, No		-0.17							
Clay stove	Yes, No		0.04							
Dining set	Yes, No		0.77	0.76			0.62	0.69		0.68
Feeding bottles	Yes, No		0.34							
Flat iron	Yes, No		0.51							
Glassware	Yes, No		0.23							
Kerosene stove	Yes, No		0.43				-0.21	-0.08	0.13	
Measuring spoon	Yes, No		0.68							
Other business machine	Yes, No		0.18							
Other kitchen equipment	Yes, No		0.09							
Other agricultural equipment	Yes, No		-0.27							
Radio	Yes, No		0.13							
Sewing machine	Yes, No		0.6				0.48	0.51	0.52	0.5
Tables	Yes, No		0.55	0.31						
Tape recorder/ stereo set	Yes, No		0.76	0.81				0.32	0.45	0.21
Thermos bottle	Yes, No		0.73							
Other house	Yes, No		0.15							
Gas stove	Yes, No		0.86				0.56	0.62	0.76	0.48
Other furniture	Yes, No			0.39	0.75	0.46	0.06	0.24		
Electricity in neighborhood	Yes, No			0.77	0.73	0.77				
Neighborhood construction material	Low, Medium, High				0.6	0.6	0.61	0.61	0.71	0.64

China cabinet	Yes, No				0.62	0.59	0.63	0.66		0.6
Motorcycle	Yes, No				0.56	0.5	0.48	0.46	0.45	0.41
Digital camera	Yes, No				0.87	0.82	0.37	0.67	0.8	0.72
Phone	Yes, No				0.86	0.88	0.85	0.77	0.28	0.48
House is neat	Low, Medium, High					0.53	0.54	0.5	0.57	0.55
Cable + TV	Yes, No						0.57	0.58	0.67	0.65
CD player	Yes, No						0.68	0.62	0.73	0.4
Karaoke machine	Yes, No						0.5	0.51	0.65	0.5
Oven	Yes, No						0.69	0.75	0.8	0.77
Pressure cooker	Yes, No						0.8	0.85	0.81	0.76
Rice cooker	Yes, No						0.77	0.76	0.72	0.64
VCR player	Yes, No						0.8	0.73	0.79	
Washing machine	Yes, No						0.79	0.76	0.78	0.7
Computer	Yes, No						0.87	0.83	0.87	0.82
Microwave	Yes, No							0.79	0.8	
Video game	Yes, No							0.64	0.75	0.75
Non-drinking water source	Low, Medium, High									0.42
Vacuum cleaner	Yes, No									0.8
Tablet	Yes, No									0.67
Electric water dispenser	Yes, No									0.65

Supplementary Table 4.15 Loadings for harmonized index and cross-sectional indices with all items for Birth to Twenty plus cohort

Asset	Categorization	Harmonized	1990-92	1997-98	2002-03	2006-07	2012-13	2017-18
	Variance explained by PC1 (%)	48.4%	41.2%	48.1%	42.0%	39.8%	60.6%	38.0%
	Correlation with harmonized	1.00	0.93	0.96	0.95	0.93	0.84	0.90
Car	Yes, No	0.65	0.69	0.64	0.61	0.72	0.67	0.68
Electricity	Yes, No	0.69	0.64					
Microwave	Yes, No	0.76		0.71	0.66	0.74	0.86	0.83
Radio	Yes, No	0.48	0.33	0.41	0.5	0.48	0.77	
Refrigerator	Yes, No	0.87	0.77	0.75	0.74	0.71	0.96	0.81
Telephone	Yes, No	0.43	0.64	0.66	0.57	0.57	0.58	0.42
Television	Yes, No	0.81	0.7	0.7	0.64		0.95	0.72
Washing machine	Yes, No	0.83	0.81	0.76	0.75	0.77	0.78	0.75
Indoor flush toilet	Yes, No	0.66	0.68	0.77	0.71	0.71		0.63
Indoor hot/cold water	Yes, No	0.64	0.74	0.79	0.77	0.63		0.66
Housing type	Low, Medium, High		0.33	0.71	0.66			0.61
House ownership	Yes, No		0.56	0.65				0.28
Solo usage of water	Yes, No		0.72		0.6	0.03		
Solo usage of toilet	Yes, No		0.68		0.5	-0.39		
DVD player	Yes, No			0.7	0.75	0.73	0.84	
Cellphone	Yes, No				0.5	0.36		0.5
Mnet	Yes, No					0.70		
Satellite TV	Yes, No					0.72		

Computer	Yes, No					0.72	0.69	0.65
Internet	Yes, No						0.58	0.54
Number of rooms per person	Crowding		0.47					0.09

Supplementary Table 4.16 Tucker index of congruence between harmonized index and cross-sectional asset indices created using same set of covariates

		Pelotas 1993 (Brazil)		INCAP (Guatemala)		NDBC (India)		CLHNS (Philippines)		Birth to Twenty plus (South Africa)
	Age at wave	**phi**	**Age at wave**	**phi**	**Age at wave**	**phi**	**Age at wave**	**phi**	**Age at wave**	**phi**
1	3-4	0.92	0-5	0.40	27-33	0.52	0	0.98	0-2	0.99
2	11-12	0.96	0-7	0.81	34-40	0.81	7-8	0.97	7-8	0.99
3	13-14	0.96	10-25	0.91	40-47	0.87	12-13	0.96	12-13	0.99
4	18	0.99	19-34	0.91	44-51	0.83	15-16	0.95	16-17	0.99
5	22	0.75	25-40	0.96			18-19	0.98	22-23	0.95
6			37-55	0.97			21-22	0.98	27-28	0.99
7			40-57	0.96			25-26	0.97		
8							33-36	0.96		

Supplementary Table 4.17 Loadings for harmonized index and cross-sectional indices with same assets as harmonized index for INCAP Longitudinal Study by Urban and Rural strata

		Harmonized	**2015-16**		**2017-18**					
	Strata		Urban	Rural	Urban	Rural				
	Variance explained by PC1 (%)	54.4%	35.5%	30.6%	37.0%	31.8%				
	Correlation with harmonized		0.98	0.97	0.96	0.95				
Asset	**Categorization**									
Crowding	Number of rooms/person	0.44	0.47	0.4	0.38	0.37				
Bicycle	Yes, No	0.59	0.29	0.09	0.18	0.15				
Car	Yes, No	0.81	0.72	0.68	0.72	0.74				
Electricity	Yes, No	0.94								
Motorcycle	Yes, No	0.72	0.39	0.14	0.57	0.59				
House ownership	Yes, No	0.09	0.23	0.15	0.26	0.33				
Radio	Yes, No	-0.17	0.04	-0.05	0.04	0.02				
Refrigerator	Yes, No	0.9	0.76	0.73	0.79	0.77				
Sewing machine	Yes, No	0.46	0.47	0.4	0.56	0.55				
Television	Yes, No	0.94		0.75	0.71	0.8				
Floor quality	Low, Medium, High	0.87	0.73	0.76	0.75	0.77				
Kitchen location	Low, Medium, High	0.68	0.7	0.66	0.56	0.49				
Roof quality	Low, Medium, High	0.82	0.77	0.84	0.74	0.76				
Sewage facility	Low, Medium, High	0.81	0.75	0.76	0.4	0.3				
Stove quality	Low, Medium, High	0.84	0.84	0.87	0.78	0.75				
Toilet quality	Low, Medium, High	0.8	0.69	0.69	0.23	0.15				
Wall quality	Low, Medium, High	0.85	0.38	0.77	0.63	0.74				

Source of water quality	Low, Medium, High	0.81		0.45	0.21	0.18				

1 Quality of roof, wall, kitchen, toilet and source of water were converted into binary variables (low vs medium) for 1967 due to absence of any values in 'High' category.

Supplementary Table 4.18 Loadings for harmonized index and cross-sectional indices with same assets as harmonized index for Cebu Longitudinal Health and Nutrition Study for Rural strata

		Harmonized	1983	1991	1994	1998	2002	2005	2009	2018
	Variance explained by PC1 (%)	35.5%	24.0%	40.6%	39.2%	40.4%	31.0%	34.3%	35.4%	35.1%
	Correlation with harmonized	1.00	0.97	0.99	0.95	0.99	0.99	0.99	0.99	0.99
Asset	**Categorization**									
Number of rooms per person	Crowding	0.33	0.3	0.53	0.53	0.46	0.38	0.36	0.35	0.37
Air conditioning	Yes, No	0.8							0.9	0.93
Bicycle	Yes, No	0.36	0.42	0.48	0.43	0.38	0.43	0.33	0.33	0.39
Car	Yes, No	0.81								0.91
Chicken/poultry	Yes, No	-0.18	-0.36	-0.33	-0.32	-0.29	-0.33	-0.25	-0.18	-0.43
Electric fan	Yes, No	0.78		0.91	0.88	0.9		0.86	0.83	0.79
Electric iron	Yes, No	0.87		0.89	0.85	0.84	0.83	0.82	0.78	0.74
Electricity	Yes, No	0.83		0.89		0.87	0.84	0.82	0.81	
Jepny	Yes, No	0.65						0.67	0.82	0.6
Living room set	Yes, No	0.71	0.64	0.77	0.7	0.69	0.7	0.74	0.55	0.66
Other appliances	Yes, No	0.38			0.65	0.68	0.08			
House	Yes, No	0.09	-0.31				-0.06	0.18	0	-0.05
Refrigerator	Yes, No	0.88		0.88	0.88	0.88	0.85	0.84	0.84	0.78
Cleanliness of are where food is stored	Low, Medium, High	0.49	0.4	0.54	0.65	0.57	0.42	0.45	0.6	0.48
Cooking fuel	Low, Medium, High	0.82		0.76	0.83	0.84	0.79	0.8	0.82	0.75
Garbage disposal	Low, Medium, High	0.36	0.16	0.25	0.09	-0.18	0.48	0.51	0.47	0.35

Condition of area for excreta	Low, Medium, High	0.25	0.29	0.32	0.43	0.34	0.08	0.19	0.3	0.35
Lighting	Low, Medium, High	0.91	0.77	0.89		0.87	0.86	0.75	0.88	
Housing material	Low, Medium, High	0.66	0.61	0.64	0.75	0.7	0.62	0.72	0.7	0.69
Neighborhood excreta removal	Low, Medium, High	0.56		0.21	0.41	0.24	0.02	0.16	0.23	0.31
Neighborhood garbage removal	Low, Medium, High	0.61		0.37		0.53	0.14	0.13	0.34	0.3
Drinking water	Low, Medium, High	0.53	0.72	0.53	0.42	0.55	0.59	0.52	0.2	0.8
Toilet	Low, Medium, High	0.79	0.77	0.76	0.75	0.81	0.83	0.8	0.87	0.92
Beds	Yes, No	0.7	0.57	0.54	0.69	0.57	0.58	0.74	0.53	0.5
Boat	Yes, No	-0.02								
Cattle (cows or carabaos)	Yes, No	-0.32	-0.43	-0.32	-0.33	-0.42	-0.31	-0.25	-0.22	-0.41
Farm animals (goat, horse, pig etc)	Yes, No	-0.31	-0.31	-0.28	-0.26	-0.23	-0.23	-0.24	-0.23	-0.28
Other vehicles (banca, motorcycle or tricycle with side-car etc)	Yes, No	0.18	0.03				0.33	0.31	0.31	
Truck or bus	Yes, No	0.52								
Television	Yes, No	0.75		0.89	0.8	0.77	0.76	0.71	0.65	0.15

Supplementary Table 4.19 Loadings for harmonized index and cross-sectional indices with same assets as harmonized index for Cebu Longitudinal Health and Nutrition Study for Urban strata

		Harmonized	1983	1991	1994	1998	2002	2005	2009	2018
	Variance explained by PC1 (%)	35.5%	38.4%	41.4%	40.2%	39.6%	31.6%	32.4%	34.1%	35.4%
	Correlation with harmonized	1.00	0.98	0.99	0.99	0.98	0.99	0.99	0.98	0.99
Asset	**Categorization**									
Number of rooms per person	Crowding	0.33	0.29	0.51	0.53	0.48	0.34	0.43	0.41	0.24
Air conditioning	Yes, No	0.8					0.85	0.86	0.88	0.86
Bicycle	Yes, No	0.36	0.23	0.34	0.31	0.3	0.26	0.17	0.14	0.21
Car	Yes, No	0.81						0.81	0.89	0.86
Chicken/poultry	Yes, No	-0.18	0.02	-0.07	-0.07	-0.01	-0.07	-0.07	-0.07	0.02
Electric fan	Yes, No	0.78	0.89	0.86	0.87	0.82		0.74	0.77	0.62
Electric iron	Yes, No	0.87	0.83	0.83	0.84	0.81	0.8	0.76	0.77	0.79
Electricity	Yes, No	0.83		0.87	0.87	0.88	0.7			
Jepny	Yes, No	0.65					0.57	0.64	0.65	0.62
Living room set	Yes, No	0.71	0.81	0.79	0.81	0.77	0.76	0.78	0.63	0.73
Other appliances	Yes, No	0.38		0.81	0.77	0.75	0.18	0.25		
House	Yes, No	0.09	-0.01	-0.01	0	0.07	0.09	0.17	0.13	0.2
Refrigerator	Yes, No	0.88	0.93	0.88	0.86	0.89	0.81	0.83	0.85	0.87
Cleanliness of are where food is stored	Low, Medium, High	0.49	0.53	0.68	0.68	0.62	0.66	0.63	0.66	0.67
Cooking fuel	Low, Medium, High	0.82	0.67	0.74	0.77	0.76	0.78	0.76	0.79	0.56
Garbage disposal	Low, Medium, High	0.36	0.28	-0.01	-0.25	-0.27	0.38	0.37	0.42	0.35

Condition of area for excreta	Low, Medium, High	0.25	0.37	0.54	0.47	0.51	0.55	0.49	0.49	0.49
Lighting	Low, Medium, High	0.91	0.83	0.86	0.87	0.85	0.74			0.91
Housing material	Low, Medium, High	0.66	0.72	0.78	0.74	0.72	0.72	0.67	0.76	0.76
Neighborhood excreta removal	Low, Medium, High	0.56		0.5	0.42	0.5	0.44	0.48	0.46	0.5
Neighborhood garbage removal	Low, Medium, High	0.61		0.57	0.41	0.55	0.55	0.49	0.53	0.5
Drinking water	Low, Medium, High	0.53	0.71	0.22	0.34	0.31	0.37	0.37	-0.18	
Toilet	Low, Medium, High	0.79	0.66	0.66	0.64	0.64	0.67	0.74	0.78	
Beds	Yes, No	0.7	0.72	0.69	0.67	0.66	0.58	0.67	0.55	0.58
Boat	Yes, No	-0.02								
Cattle (cows or carabaos)	Yes, No	-0.32								
Farm animals (goat, horse, pig etc)	Yes, No	-0.31	0.11	-0.05	0.02	0.01	0.04	0.02	0	
Other vehicles (banca, motorcycle or tricycle with side-car etc)	Yes, No	0.18	0.31				0.04	0.04	0.02	-0.13
Truck or bus	Yes, No	0.52								
Television	Yes, No	0.75	0.89	0.85	0.83	0.82	0.5	0.41	0.41	0.3

Supplementary Table 4.20 Correlation of schooling and health measures with cross-sectional asset index in corresponding wave among those who participated in adulthood

		Pelotas 1993 (Brazil)		INCAP (Guatemala)		NDBC (India)		CLHNS (Philippines)		Birth to Twenty plus (South Africa)
	Age at wave	rho	Age at wave	rho	Age at wave	rho	Age at wave	rho	Age at wave	rho
Schooling										
1	3-4[a]	0.55	0-7 [a]	0.14	0-2[b]	Not available	0[a]	0.58	0-2[a]	0.27
2	11-12[a]	0.60	10-25	0.31	27-33	0.48	7-8[a]	0.56	7-8[a]	0.30
3	13-14[a]	0.57	19-34	0.3	34-40	0.48	12-13[a]	0.56	12-13[a]	0.29
4	18	0.47	25-40	0.37	40-47	0.44	15-16	0.50	16-17	0.19
5	22	0.44	37-55	0.5	44-51	0.52	18-19	0.53	22-23	0.21
6			40-57	0.5			21-22	0.53	27-28	0.30
7							25-26	0.54		
8							33-36	0.56		
HAZ at 2y										
9	2[b]	Not available	2	0.10	2[b]	Not available	2	0.25	2	0.12
BMI in adulthood										
10	22	-0.05	37-55	0.18	44-51	0.23	33-36	0.19	22-23	0.04

Sample sizes among those who participated in adulthood varied for above Pearson correlations: Brazil (995;3608;3576;3519;3805;3559), Guatemala (1346;931;641;821;1160;1265;723;1143), India (868;807;790;841;828), Philippines (1326; 1321; 1325; 1325; 1303; 1311; 1274; 1249; 1326; 1285;1304), and South Africa (1132;999;1071;1201; 1274; 1393; 856; 1202). This is not the sample size of participants at each wave (non-monotone missingness).

a Correlation with maternal schooling. Values from 1967 and 1975 were combined for Guatemala (n = 2392).

b Temporally harmonized asset index was not available in childhood for NDBC and before 3 years for Pelotas 1993

Supplementary Table 4.21 Correlation of harmonized index with alternate factor extraction procedures

Factor extraction	Correlation matrix	Pelotas 1993 (Brazil)	INCAP (Guatemala)	NDBC (India)	CLHNS (Philippines)	Birth to Twenty plus (South Africa)
Exploratory Factor Analysis	Polychoric	0.99	0.95	0.99	0.96	0.99
Exploratory Factor Analysis	Pearson	0.99	0.94	0.99	0.94	0.99
Principal Component Analysis	Pearson	1.00	0.99	1.00	0.99	1.00
Multiple Correspondence Analysis		0.99	0.98	0.99	0.99	1.00

Chapter 5 Conditional wealth to estimate association of wealth mobility with health and human capital in low- and middle-income country cohorts

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Short running head: Identifying sensitive life stages of wealth accumulation

Abbreviations: CLHNS: Cebu Longitudinal Health and Nutrition Survey; EFA: Exploratory Factor Analysis; LMIC: Low- and middle-income countries; MCA: Multiple Correspondence Analysis; PCA: Principal Component Analysis; SD: standard deviation; SEP: Socio-economic position

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Data availability statement: The raw datasets are available at the Carolina Population Center Dataverse: https://dataverse.unc.edu/dataverse/cebu. The code and data for the analysis is available at https://github.com/jvargh7/conditional-wealth.

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ABSTRACT

Temporally harmonized asset indices allow the study of changes in relative wealth (mean, variance, social mobility) over time. Conditional measures are the unexplained residuals of an indicator regressed on its past values. Using such measures, previously used to study the relative importance of key life stages for anthropometric growth, we can identify specific life stages during which changes in relative wealth are important. We discuss the assumptions, strengths and limitations of this methodology as applied to relative wealth. We provide an illustrative example using a publicly-available longitudinal dataset and show how relative wealth changes at different life stages are differentially associated with body mass index in adulthood.

KEYWORDS: asset index, conditional wealth, life course, relative deprivation, social mobility

1. Introduction

Wealth is a robust measure of socio-economic position where individuals are vulnerable to economic shocks from unemployment and lack of social safety nets (1). Asset-based indices have been widely used in national, sub-national and community surveys as proxies for household wealth and material wellbeing, due to their relative ease of data collection and computation. Typically, household asset indices are estimated as the first principal component of a dataset comprising of a household's possession of durables (assumed public goods), housing characteristics, and public utilities (2). In societies where food expenditures constitute a minority of total expenditure and where households do not experience transitory shocks to expenditure, household asset indices are correlated with non-food expenditures (3, 4). Asset indices as measures of wealth have several limitations. First, asset indices are usually estimated from an instrument that ascertains possession of a restricted number of contextually relevant assets. Thus, asset indices may not capture non-asset wealth (such as savings or financial instruments) nor the quantity, quality, functioning, availability of substitutes and technological generation of these assets. Second, the distribution of asset indices may not reflect the true distribution of wealth due to issues of clumping (many households having the same value of the index) and truncation (failure to differentiate households at the ends of the distribution) (5). Third, asset indices may include community infrastructure items that display an urban bias (4, 6-10). To address this issue, methodologists have suggested creating urban and rural indices separately (1). Despite these and other criticisms, asset indices are a reliable marker of one's societal standing in countries where many individuals do not have access to basic goods and services (1, 11).

A longitudinal measure of wealth is useful if it could describe both individual and population level characteristics of wealth distribution over time. Although both cross-sectional asset indices for birth cohorts as well as harmonized asset indices for serial cross-sectional studies are useful in their own right, a temporally-harmonized asset index allows us to examine distributional characteristics beyond these indices (**Table 5.1**). The application of the methodology to create cross-sectional indices for cohort studies, as proposed by Filmer and Pritchett, may provide an opportunity to examine redistribution in relative position (change in rank) but cannot capture mean changes in wealth, changes in asset inequality or magnitude of redistribution of relative position (2). This is because, firstly, such indices are standardized to zero mean and unit variance. Secondly, a unit change may have different interpretations between two cross-sectional study waves due to differences in asset loadings. However, application of methods previously used for serial cross-sectional data to longitudinal data may allow us to study other properties of wealth over time. We review these methods (Section 2), define the characteristics of wealth distributions (Section 3) and extend the temporally harmonized index to explain relative wealth mobility over time in cohort studies using conditional measures in later sections.

2. Cross-sectional and temporally-harmonized asset indices

2.1 Serial cross-sectional studies

Asset indices, as originally developed, can reliably measure one's relative position at a single point in time, but by nature of their construction can capture neither a change in asset scores nor a change in asset-based inequality in populations. To address these issues, efforts have been made to harmonize asset indices to compare relative wealth between or within countries using cross-sectional data (10, 12). The International Wealth Index (IWI) is the first component of a PCA applied to data on 12 standard items (seven consumer durables, three housing characteristics, two public utilities) in 165 cross-sectional surveys from 97 countries. The IWI demonstrates an increase in mean wealth over time, and is robust to dropping assets and surveys. The Comparative Wealth Index (CWI) uses as an anchor a reference survey (Vietnam 2002 DHS in the original paper) to compute the relative position of households in space and time (13). The Absolute Wealth Estimate (AWE) uses the asset index, national GDP per capita and a measure of inequality to compute a household's income based on their relative position on the asset index (14).

Asset indices created using different dimensionality reduction techniques (PCA, exploratory factor analysis, multiple correspondence analysis, categorical PCA) may vary in their estimate of wealth even after standardization to unit variance. However, these indices are often rank correlated (10), signifying the importance of sensitivity analyses using alternate methodologies while dealing with estimates of small magnitude for association of asset indices with health.

2.2 Longitudinal studies

Previous methodological approaches used to compare cross-sectional studies of populations over time do not permit an exploration of individual wealth trajectories, but could be extended to longitudinal studies. As an example, using five longitudinal birth cohorts, we previously constructed temporally-harmonized indices from a common set of contextually-relevant assets and polychoric PCA, separately for each cohort, using an approach similar to the International Wealth Index (15). Similar to harmonized indices from serial cross-sectional studies, temporally-harmonized indices allow us to quantify mean gains in wealth and changes in variance of wealth distribution over time. However, temporally-harmonized indices additionally allow us to identify the changes in individual level wealth, magnitude of changes in relative position and relative importance of wealth at different life stages for later-life outcomes. Others have used similar approaches to track material standards of living, and relative distribution of wealth (16-19). The harmonized indices for the birth cohorts were robust to dropping assets and study waves, were correlated with cross-sectional or region-stratified (by urbanicity) indices, and were rank correlated with indices constructed using alternate dimensionality reduction techniques (PCA, EFA, MCA).

3. Changes in wealth, asset inequality and relative position

We define the key characteristics of the wealth distribution for a longitudinal study as follows for an individual ‘i' at two time points ‘t’. First, a positive change in wealth for the population (Eq 1) and an individual (Eq 2) are reflected as an increase in the factor score of the temporally-harmonized asset index. This could be either due to an increase in number of assets that load positively or accumulation of higher value assets. Second, an increase in asset-based inequality is equivalent to a positive difference in the relative variance (Eq 3; fraction of variance attributable to each time point) between study waves of the longitudinal cohort as defined by McKenzie et.al. (20). Third, the net relative position (Eq 4) for individuals in the cohort is zero since the cohort is closed. We define the following quantities:

Change in mean wealth: $E[w_{i,t=2}] - E[w_{i,t=1}]$ [1]

Change in individual wealth: $w_{i,t=2} - w_{i,t=1}$ [2]

Change in asset-based inequality: $\sqrt{\frac{\mathrm{Var}[W_{t=2}]}{\sum \mathrm{Var}[W_{t=T}]}} - \sqrt{\frac{\mathrm{Var}[W_{t=1}]}{\sum \mathrm{Var}[W_{t=T}]}}$ [3]

Change in relative position for an individual: $\mathrm{Rank}(w_{i,t=2}) - \mathrm{Rank}(w_{i,t=1})$ [4]

Harmonized asset indices created from serial cross-sectional surveys have demonstrated an increase in mean wealth over time in low- and middle-income countries (5). Results using a temporally harmonized index constructed using polychoric PCA from China Health and Nutrition Survey showed a consistent increase in mean wealth over time while asset-based inequality trended upward from 1989, similar to consumption inequality in a cohort of 4400 households, with a peak in 2000 (21). Asset-based inequality subsequently decreased, driven by a decline in inequality among urban households. Consistent with a methodology proposed earlier by McKenzie (2005) that considered the lack of scale invariance for PCA-derived indices, that study partitioned the total temporal variance into variance by study wave (20). A comparative cross-sectional analysis of Demographic and Health Surveys estimated Gini coefficients for asset-based inequality using an index similar to the International Wealth Index (22). A study using pooled cross-sectional surveys from South Africa identifies issues while computing asset-based inequality using the McKenzie approach and indices created from a PCA, including how rare assets may distort index estimation and negative loadings on the index (from negative correlation of assets) that may not satisfy axioms of inequality analysis (10). The authors propose using an uncentered PCA (UPCA) that does not produce such loadings and inspecting the joint distribution of assets before any substantive analysis.

4. Conditional wealth: magnitude of change in an individual's relative position

4.1 Conditional measures versus adjusting for exposure

An 'unexplained residuals' (UR) modeling framework allows examination of the association of several measurements of an exposure and their relative importance over time with the outcome (23). These measures are often operationalized as residuals from a linear regression. However, one could use non-linear approaches to estimate conditional measures while compromising interpretability as residuals absent of correlations with all previous measures of wealth. The below equation (Eq 5) describes the mathematical quantity of conditional measure ($c_{i,t}$) for an exposure ($w_{i,t}$) as the difference beyond what is predicted by previous measures of the exposure from time 1 to t -1.

$$c_{i,t} = w_{i,t} - \widehat{w}_{i,t} = w_{i,t} - f(w_{i,1}, w_{i,2}, w_{i,3}, \dots, w_{i,t-1}) \qquad [5]$$

We demonstrate the use of conditional measures with a simple example using two time points (t = 1, 2) and exposure $w_{i,t}$ measured at time 't' for individual 'i'. A fixed effects approach for repeated measures of the exposure is provided in Eq 6. The conditional measures approach is provided in Eq 7. Previous research has demonstrated how both models are equivalent for w_2 such that $a_2 = a'_2$ (23). However, $a_0 \neq a'_0$ and $a_1 \neq a'_1$, leading to debates (see **Section 8. Limitations of the approach**) over the relevance of the anchor measure (w_1 in our case) that is used as the predictor for other measures (such as w_2), rendering it different from the fixed effects approach with repeated measures of the exposure.

$$E[y_i] = a_0 + a_1 E[w_{i,1}] + a_2 E[w_{i,2}] + \text{Covariates} \qquad [6]$$

$$E[y_i] = a'_0 + a'_1 E[w_{i,1}] + a'_2 E[c_{i,2}] + \text{Covariates} \qquad [7]$$

4.2 Conditional growth

Conditional measures have been used to study the relative importance of anthropometric growth during different life stages for adult outcomes. Positive conditional growth is a marker of faster than expected anthropometric growth. In a model to predict a later life outcome, conditional growth at each life stage has a direct interpretation, since it represents growth during a specific interval (24). For example, conditional length in first 2 years has been associated with adult height, while conditional weight between 2 and 5 years has been associated with adult BMI (25). Other studies have shown differential associations of conditional measures of growth with IQ, blood glucose, blood pressure and offspring growth (25-28).

4.3 Conditional wealth

We extend the conditional growth model to a measure derived from asset-based indices, which we call a conditional asset index. We henceforth refer to it as conditional wealth given that asset-based indices are a proxy for wealth in LMICs. Similar to conditional growth, conditional wealth would allow us to identify stages in the life course at which changes in wealth beyond that predicted by past measures of wealth are differentially associated with health outcomes. This is especially important as LMICs experience slow economic growth, high or rising wealth inequality, and intergenerational social persistence to identify sensitive periods when relative social mobility (positional mobility) is important. The importance of positional mobility assumes that relative position in the wealth hierarchy matters.

We propose that conditional wealth ($c_{i,t}$) for a life stage ‘t’ and individual ‘i’ is the difference in wealth in that life stage from that which could be predicted by all prior individual measures of wealth and the overall wealth trajectory of the population under study (Eq 8). For our previous example with two time points, which could be extended to more than two time points, where $g(w_{i,1}) = \hat{w}_{i,2}$, we propose:

$$w_{i,2} = g(w_{i,1}) + c_{i,2} \qquad [8]$$

Conditional wealth is the unexplained residual of the regression of wealth at time 2 as the dependent variable on all previous measures of wealth (in this case time 1) as linearly associated independent variables (Eq 9).

$$w_{i,2} = b_0 + b_1\, w_{i,1} + c_{i,2} \qquad [9]$$

such that $E[c_{i,2}] = 0$; $Var[c_{i,2}] = \sigma^2_{t=2}$

Re-writing Eq 9, we define conditional wealth as the magnitude of change in relative position for an individual: $\mathbf{c}_{i,2} = \mathbf{w}_{i,2} – [b_0 + b_1\, \mathbf{w}_{i,1}]$. The above example could be extended to more than two time points easily and we demonstrate the same empirically in Section 7.4.

A previous study by Arnold et. al. has clearly demonstrated appropriate confounder adjustment mathematically and using causal diagrams for conditional measures (or unexplained residuals) (23). Arnold et. al. recommend adjustment for confounders at both stages, i.e. during construction of conditional measures and during estimation of association with outcomes (Eq 10). The conditional wealth derived using the Arnold et. al. approach would then be uncorrelated with previous measures of wealth and with the confounders (23). Assume X_1 is a predictor of wealth at time 1 (e.g. maternal schooling), and X_2 is a predictor of conditional wealth, and is partly predicted by w_1 (e.g. attained schooling). A directed acyclic graph (DAG) for how wealth, conditional wealth, schooling and outcome are related is provided in **Figure 5.1**. The outcome regression as per Arnold et. al. (Eq 11) is fit with the anchor measure, confounders, and conditional wealth.

$$w_{i,2} = b'_0 + b'_1 w_{i,1} + b'_2 X_{i,1} + b'_3 X_{i,2} + c'_{i,2} \qquad [10]$$

$$E[y_i] = a'_0 + a'_1 E[w_{i,1}] + a'_2 E[X_{i,1}] + a'_3 E[X_{i,2}] + a'_3 E[c'_{i,2}] \qquad [11]$$

We deviate from the approach by Arnold et. al. during the first stage (using Eq 9) since we are interested in understanding the 'absorbed effect' of omitted predictors (Eq 12) on the conditional measures (23). In this case, absorbed effect refers to the variability in conditional wealth explained by predictors of conditional measures, where $u_{i,2}$ is the error term when predicting conditional wealth.

$$c_{i,2} = d_0 + d_1 X_{i,1} + d_2 X_{i,2} + u_{i,2} \qquad [12]$$

A path analysis approach (**Figure 1A)**, where all past measures of the exposure and other covariates are predictors of the exposure at time t, is equivalent to the conditional measures approach (**Figure 1B**). Studies estimating the association of conditional wealth with health outcomes should adjust for the first (or anchor) measure of wealth, life course covariates and past measures of conditional wealth, but not for any other wealth measure. Our final outcome regression (Eq 13) would yield equivalent regression coefficients (i.e. $a_1 = a'_1$, $a_2 = a'_2$ etc.) as Arnold et.al (Eq 11).

$$E[y_i] = a_0 + a_1 E[w_{i,1}] + a_2 E[X_{i,1}] + a_3 E[X_{i,2}] + a_3 E[c_{i,2}] \quad [13]$$

Given these estimates, our approach is intended to understand how one could intervene on conditional wealth, while at the same time get unbiased estimates of relative position effect on the outcome after appropriate confounder/covariate adjustment. Studies estimating the association of early life variables on conditional wealth should not adjust for the anchor measure since it is assumed to be uncorrelated with the conditional wealth measure (**Supplementary Fig 5.1).** There is no covariance between the anchor measure and a predictor of conditional wealth (say X_2) that also covaries with conditional wealth. For example, only the component of attained schooling, say from an intervention such as mandatory schooling, which doesn't depend on early life wealth predicts conditional wealth. Conditional wealth is, in effect, a decomposition of current wealth into explained and unexplained components that are uncorrelated with each other. Conditional wealth is therefore the magnitude of change in relative position for an individual.

4.4 Conditional wealth versus adjusting for wealth

An advantage of adjusting for conditional wealth over adjusting for wealth at different time points is in ease of interpretability. The coefficient for conditional wealth could be interpreted as the independent contributions of extraneous variations in wealth, resulting in positional mobility, to health disparities. While similar in magnitude, the coefficient for the concurrent wealth variable may alternately be interpreted as the contribution of wealth after adjusting for previous measures of wealth and other covariates.

While reporting the association of conditional wealth and other variables, one should report both (a) the predictors of conditional wealth at a life stage, and (b) the associations of conditional wealth with the health outcome after adjusting for the predictors of conditional wealth that are confounders of conditional wealth and health association. Moreover, one should check if the harmonized wealth measures used to create conditional wealth are suitably distributed continuous variables such that linear regression is an appropriate model formulation.

5. Assumptions for conditional wealth

We first state the assumptions for the temporally harmonized index for individuals.

1. Household assets, housing characteristics and public infrastructure items included are public goods, i.e. access by one family member does not prevent the access or availability of others.
2. Household wealth reflects an individual's standard of living. The harmonized index increases with increase in real and asset-based wealth.
3. Asset loadings on the harmonized index are similar over time, i.e., the relative importance of assets as indicators of household wealth are similar over time.
4. Rankings of households is similar between harmonized index and cross-sectional index for any study wave
5. Criterion validity: Positively associated with other measures of socio-economic position such as schooling, subjective social status and income
6. The harmonized index can distinguish household wealth over the range of the index
7. The harmonized index can distinguish household wealth at extrema of distribution (between poor and very poor, between rich and very rich)

The latter two assumptions (clumping and truncation respectively) could be observed from exploratory plots, but are not verifiable due to the absence of a gold-standard marker of wealth.

We now state the following assumptions for conditional wealth to be a valid measure of magnitude of change in relative position beyond that predicted by past measures of wealth.

1. *Temporal consistency*: One unit change in conditional wealth should be interpretable in the same scale at different study waves
2. *Appropriate model specification*: The model for creating conditional wealth (as unexplained residuals) is specified correctly, such that residuals are independently and identically distributed, and free of heteroskedasticity.
3. *Appropriate interval selection*: Conditional wealth should have variance. Canalization of wealth, i.e., high rank correlation between successive time points, would lead to low variance in conditional wealth.

6. Conditional wealth and changes in wealth, asset inequality and relative position

Negative conditional wealth does not imply that an individual's wealth decreases. Also, positive conditional wealth does not necessarily imply that an individual's wealth increases. As shown in **Figure 5.2** (additional examples in **Supplementary File 5.2**) for three example individuals at two time points, mean wealth increases in panels A to D, and decreases in panels E to H. Conditional wealth at time 2 is the vertical distance between the individual trajectory (solid line) and predicted trajectory of each individual based on the cohort (dashed line). For example, in panel A, conditional wealth at time 2 is positive for individual 1, zero for individual 2 and negative for individual 3. In panel D, although the conditional wealth for individual 1 is negative, their overall wealth change is positive due to the large mean change in wealth.

A change in wealth inequality occurs if difference in variance between the two time points is non-zero. Variance of wealth at time 2 consists of explained and unexplained (conditional wealth variance) components as described in Eq 9. When mean wealth increases, inequality (variance of wealth at time 2) may increase, decrease or stay the same as shown in panels A to C. Similarly, when mean wealth decreases, inequality may increase, decrease or stay the same as shown in panels E to G. The change in inequality depends on the magnitude of slope and variance of conditional wealth.

In all panels except B, C, F and G, the relative position of different individuals stay the same – implying no positional mobility, i.e. change in individuals' relative positions. Panels C and G signify an unusual case when the bottom and top ranked individuals switch places under a case of no change in wealth inequality but changes in mean wealth (increase for panel C, decrease for panel G). One can imagine scenarios when positional changes occur under increasing and decreasing wealth inequality (such as panels B and F).

An individual with positive conditional wealth is more likely than someone with zero or negative conditional wealth to move up the ranks of wealth. Whether or not they move up or down the ranks depend on their initial wealth relative to mean initial wealth and their conditional wealth relative to predicted change in wealth. However, an important takeaway is that the proportion of variance in wealth at time 2 that is conditional wealth variance explains the extent of positional mobility. Since ($\mathbf{w}_{i,2} = b_0 + b_1 \mathbf{w}_{i,1} + \mathbf{c}_{i,2}$), if b_1 is non-zero, then conditional wealth variance is less than variance of wealth at time 2. If past wealth is unable to explain future wealth (i.e. $b_1 \approx 0$), then positional mobility is high. In a context of rising inequality and no positional mobility, the share of variance unexplained by past wealth may be zero. In such a case, conditional wealth is also zero by virtue of how it is constructed. In such a context, relative social mobility (positional mobility) is non-existent. Associations with health, under a framework where only relative position matters for health, would therefore be entirely explained by past wealth.

7. Illustrative example using conditional wealth

7.1 Study Population

We used publicly available data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS) – a cohort of women and children in the Philippines (29). The data were downloaded from the Carolina Population Center Dataverse (https://dataverse.unc.edu/dataverse/cebu). The CLHNS cohort was established with the identification and recruitment of all pregnant women from a single-stage cluster-sample of 17 urban and 16 rural barangays in Metro Cebu in 1983. Among the 3327 women interviewed at baseline, there were 3080 singleton and 26 multiple births, which followed up during subsequent waves. The harmonized index for CLHNS that we used included seven publicly available study waves (1983, 1991, 1994, 1998, 2002, 2005, 2009) and data on the 2017-18 wave shared privately with the authors, to be consistent with what was previously reported (15). However, a sensitivity analysis that did not include the 2017-18 wave showed rank correlation (r = 1.00) with the original reported index. We restricted our analysis to singleton births who participated in 2009 (n = 1709; age 26-27). The proportion of missingness for wealth was less than 4% in any study wave. Hence, for ease of analysis and interpretation, we restricted our analysis to a complete-case scenario (n = 1581). We compared the early life and adult characteristics of those were included and excluded based on complete-case analysis, and found no systematic differences (**Supplementary Table 5.1**).

7.2 Variable specification

Exposure: Wealth was measured by using questionnaires on assets and housing characteristics (such as building material, toilet, source of water etc) over the life course. We pooled data on 30 assets (e.g. car, television, house ownership), housing characteristics (e.g. housing material, rooms per resident) and public utilities (e.g. garbage collection) collected during study waves from 1983 to 2018 and created a temporally harmonized asset index, as reported previously (15). We used a polychoric principal components analysis, extracted the first component and standardized it to unit variance.

We compute the conditional wealth as the residual from a linear regression which predicts wealth at one time point using all previous measures of wealth. We did not adjust for confounders of wealth and outcome association while creating conditional wealth, consistent with the methodology for conditional growth (25).

Outcome: Height and weight were measured in 2005 and 2009 respectively. Since adult height stabilizes after age 20, we used height from 2005 to compute body mass index in 2009 as weight (in kg) per square meters.

Covariates: Maternal schooling, maternal age, birth order, sex and residence (rural or urban) were collected upon enrollment in 1983. Additionally, every survey collected information on current residence that was classified as urban or rural based on administrative databases. Attained schooling and status of formal employment were collected in adulthood.

7.3 Statistical Analysis

We estimated the mean and variance for wealth and conditional wealth at each study wave. We computed change inequality as per the formula in Section 3. We then computed the proportion of variance in wealth that was unexplained, and is an indicator of positional mobility. We first identified the predictors of conditional wealth (as per Section 4.3) using multivariable linear regression. Next, we estimate the association of wealth in childhood and conditional wealth at different life stages with body mass index to identify stages of the life course at which changes in relative position were associated with BMI at 26y. We repeated the analysis after stratifying by sex, since patterns of weight status are known to differ by sex in LMICs (30).

All analysis was carried out using R 3.6.1. The code for the analysis is available on https://github.com/jvargh7/conditional-wealth.

7.4 Results

Our results suggest that mean wealth increased over time (**Table 5.2**). We display the univariate and bivariate distribution of wealth at different study waves in **Fig 5.3**. As expected, correlations between wealth measures decrease as they are further apart in time. Conditional wealth at different study waves were normally distributed (**Supplementary Fig 5.2**). Inequality increased from 1983 to 1991 but then remained steady. The share of variance explained by conditional wealth (or unexplained variance in wealth) was 51% in 1991 and then decreased to nearly 30% afterwards. Maternal schooling was positively associated and whether the participant resided in a rural area in the corresponding study wave was negatively associated with conditional wealth in early life (**Table 5.3**). Apart from these measures, both attained schooling (from 2002 onwards) and formal employment were positively associated with conditional wealth in adulthood. We demonstrate the implications of varying adjustment for wealth and conditional wealth on regression coefficients in **Supplementary Table 5.2**. Association of body mass index with wealth and conditional wealth at different life stages suggest heterogeneity by sex in 1983, 1998 and 2009 though we did not formally explore this (**Fig 5.4, Supplementary Table 5.3**).

8. Limitations of the approach

Firstly, asset-based measures of relative wealth are prone to issues of interference. By virtue of construction of asset-based indices in a study population, an individual's membership in a high wealth stratum leads to another individual's membership in a low wealth stratum and consequently the others' health outcomes (31, 32).

Second, studying SEP (as a function of material, human and social capital) or wealth (as a latent construct measured through the asset index) leads to issues of 'compound treatments with multiple versions', i.e. an exposure that comprises of more than one exposure (in this case, combinations of assets and housing characteristics). The asset index comprises of a data-derived weighted (linear) composite of items such as durable goods, housing characteristics and infrastructure. When calculating the asset index, an individual could arrive at the same score through different combinations of items (perfect substitution) (33). This is a possible violation of the consistency assumption such that individuals who receive an exposure in the real world display the same outcome as they would have if they receive the exposure in the counterfactual world (34, 35). Furthermore, the items comprising the index could be associated with the health outcome through mechanisms other than the latent construct signified by the index. As an example, possessing a television could be associated with social capital (such as during group viewing of sports or peer-interaction during play hours) or information (versus other media such as radio or internet). Another example is flooring or water source, which determine exposure to infections. In our analysis, we assume treatment-variation irrelevance wherein the same associations are observed independent of which set of items contribute to a participant's asset index score. Given the possible alternate mechanisms through which the assets might operate jointly (or independently) and knowing that they are not well characterized, it might not be possible to develop interventions from our analysis in practice.

Third, similar to the temporally harmonized index, we do not account for individuals selecting themselves into higher wealth because of increased availability of infrastructure items through migration (from rural to urban areas for employment). We also do not account for changes in household composition (through marriage or separation) that may result in higher (or lower) scores than that of their original birth household (15).

Fourth, a limitation of conditional wealth that is not present in conditional growth is the possibility of treatment-confounder feedback (35). Early life wealth and conditional wealth may predict confounders of the association (such as attained schooling) between later life conditional wealth and health outcomes. This may bias the association of early life measures with health outcomes.

Fifth, as opposed to an estimation of the association between life course wealth measures and health using outcome regression, we adopt a two-step approach that first estimates conditional wealth, and then estimates the association of the anchor measure and conditional wealth with health, after adjusting for confounders. Further research into the possibility for incorrect standard error estimation, as is the case with manual two-stage estimation for instrumental variable analysis, ought to be considered.

Finally, coefficients for conditional measures cannot be interpreted independent of the anchor (usually first) measure that was used. Our outcome model assumes that one's absolute wealth at different time points is not associated with health, and all associations are explained by one's relative position and changes in the same. Conditional measures are able to explain the role of relative wealth mobility only conditional on the anchor measure. The coefficient for the anchor measure would be higher if positively correlated with the outcome or lower if negatively correlated with the outcome compared to a model where wealth measures at different time points are entered into the model. This is due to the anchor measure capturing the association of changes in mean wealth with the outcome, while conditional measures capture association of changes in relative wealth with the outcome. Consequently, it may falsely suggest designing only interventions that target only the anchor measure as opposed to measures at other time points. For example, in a context of rising inequality and low positional mobility (or high social persistence) irrespective of changes in mean wealth, the anchor measure entirely explains the association of relative position with health. We could also conceptualize an alternate formulation of conditional wealth with the anchor measure as the last measurement. This may answer a different set of questions such as the relative importance of prior relative wealth mobility, beyond current wealth, for a health outcome (24).

9. Summary

Conditional measures are a useful statistical decomposition of exposures measured longitudinally. Beyond previous established applications such as identifying periods of growth that are associated with health and human capital, applying this technique to harmonized wealth measures may help identify life stages where changes in relative wealth are associated with health. The nature of conditional wealth implies that longitudinal data at an individual or household level are required to construct such measures. Studies such as the Young Lives cohorts, Millennium Villages Project, WHO SAGE surveys and other cohorts from LMICs that have collected data on asset-based wealth are sources of such data. Although results with and without decomposing wealth into conditional measures are the same, the additional utility of identifying predictors of relative wealth changes at different life stages is important from a public health perspective.

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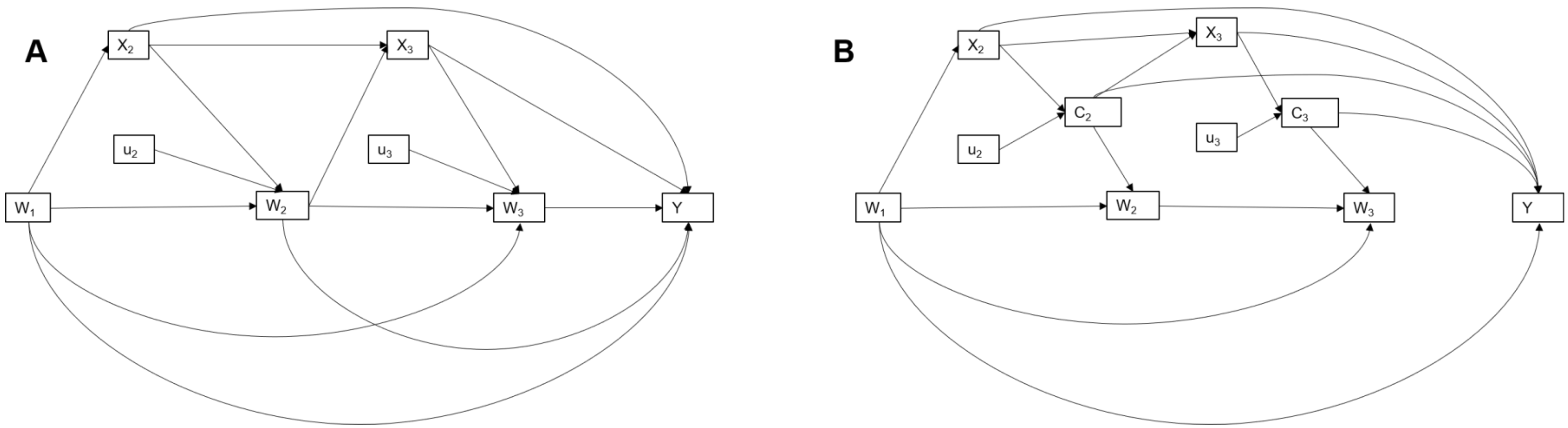
Table 5.1 Comparison of approaches and their relative contributions

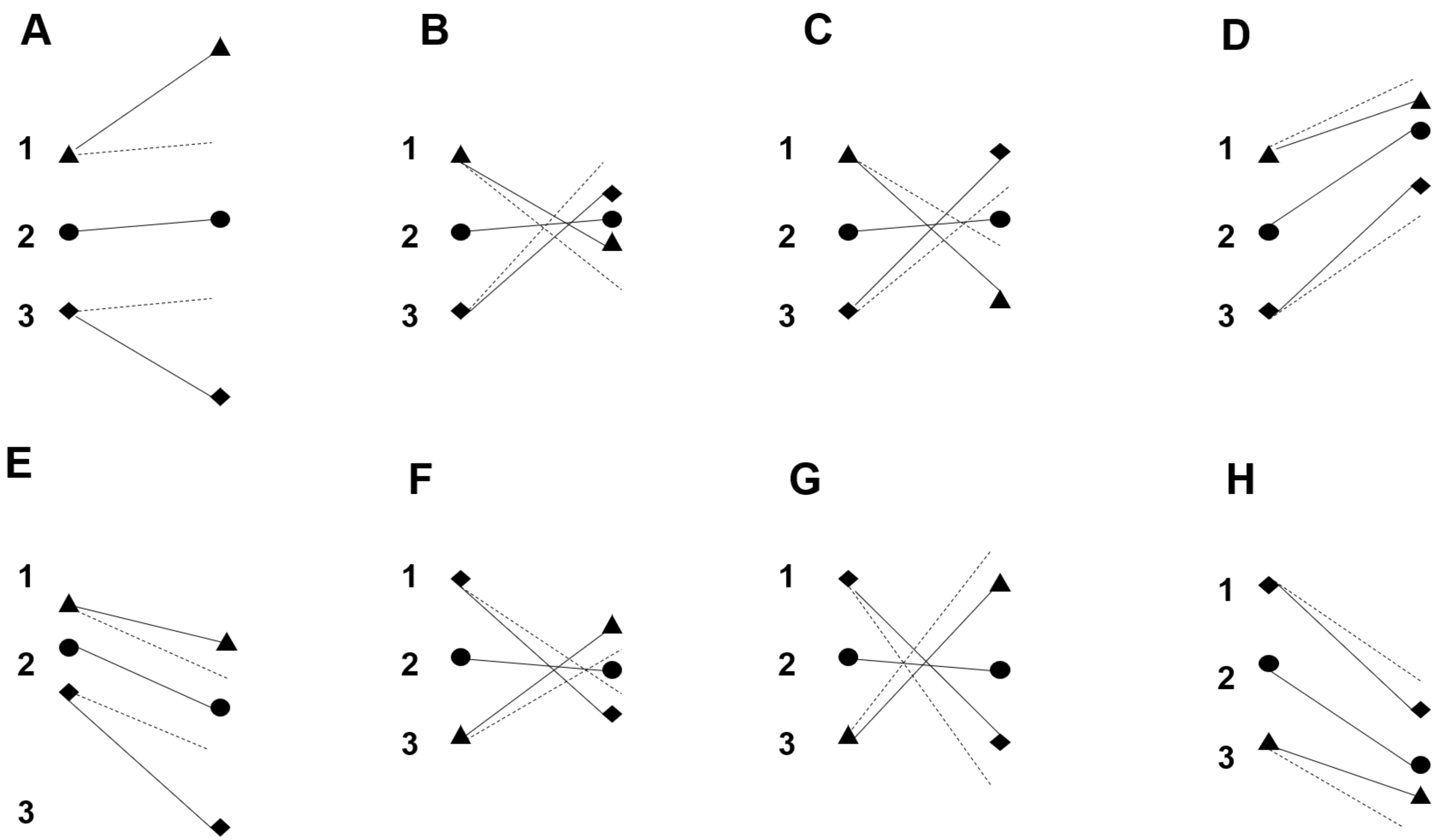
	Study type	Change in mean wealth	Change in individual wealth	Change in asset-based inequality	Change in individual's relative position	Magnitude of change in individual's relative position
Cross-sectional asset index (independent construction)	Serial cross-sectional surveys	No	No	No	No	No
	Cohort	No	No	No	Yes	No
Harmonized asset index (pooled construction)	Serial cross-sectional surveys	Yes	No	Yes	No	No
	Cohort	Yes	Yes	Yes	Yes	Yes

Figure 5.1 Conceptual framework for wealth and conditional wealth in longitudinal studies



W_t are the measures of wealth, Y is the health outcome, X_t are the covariates associated with wealth like schooling and employment, C_t are conditional wealth measures or the magnitude of change in relative position. Panel (A) is the traditional framework for study of wealth with Y. In panel (B), we conceptualize conditional wealth (C_t), an extraneous contribution to current wealth beyond past measures of wealth. W_t and C_t may also be predicted by other unmeasured variables (U_t) that are not confounders of the wealth-outcome relationship.

Figure 5.2 Examples of changes in wealth at two time points for scenarios of mean, variance and relative position



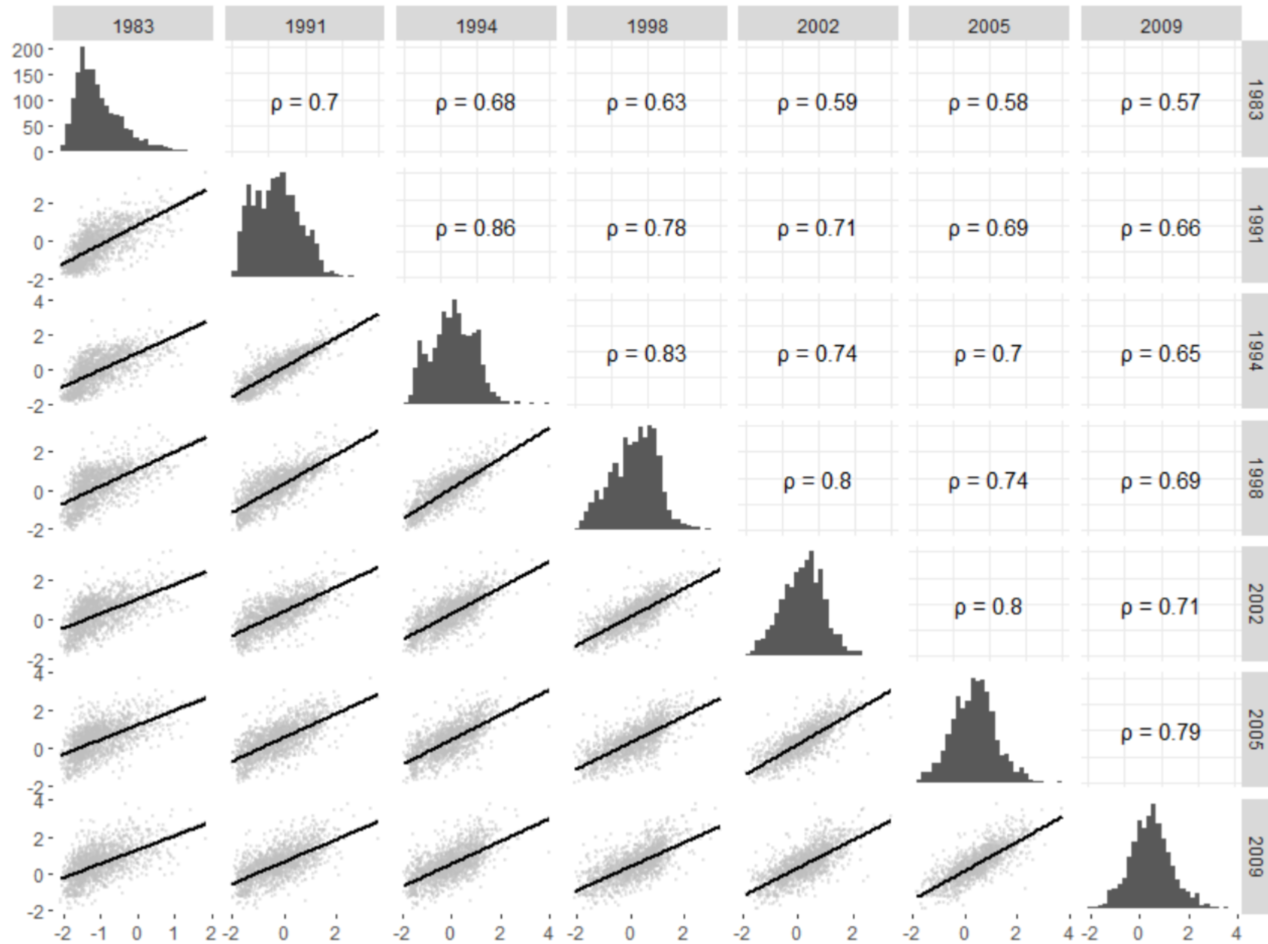
The different shapes represent wealth of individuals at two different time points. Additional examples are available in **Supplementary File 2**.

Table 5.2 Summary of harmonized wealth and conditional wealth for Cebu Longitudinal Health and Nutrition Survey 1983-2009 (n = 1581)

Year	Wealth	Change in mean wealth	Change in wealth inequality from preceding wave	Conditional wealth	Proportion of variance unexplained
1983	-1.04 ± 0.62				
1991	-0.24 ± 0.91	0.80	0.13	0 ± 0.65	0.51
1994	-0.05 ± 0.89	0.19	-0.01	0 ± 0.44	0.25
1998	0.16 ± 0.88	0.22	0.00	0 ± 0.47	0.29
2002	0.25 ± 0.79	0.08	-0.04	0 ± 0.45	0.33
2005	0.44 ± 0.83	0.20	0.02	0 ± 0.47	0.32
2009	0.49 ± 0.85	0.04	0.00	0 ± 0.49	0.34

Values are in mean ± standard deviation for harmonized wealth and conditional wealth (units same as harmonized wealth).

Figure 5.3 Joint distribution of temporally harmonized wealth at different study waves (n = 1581)



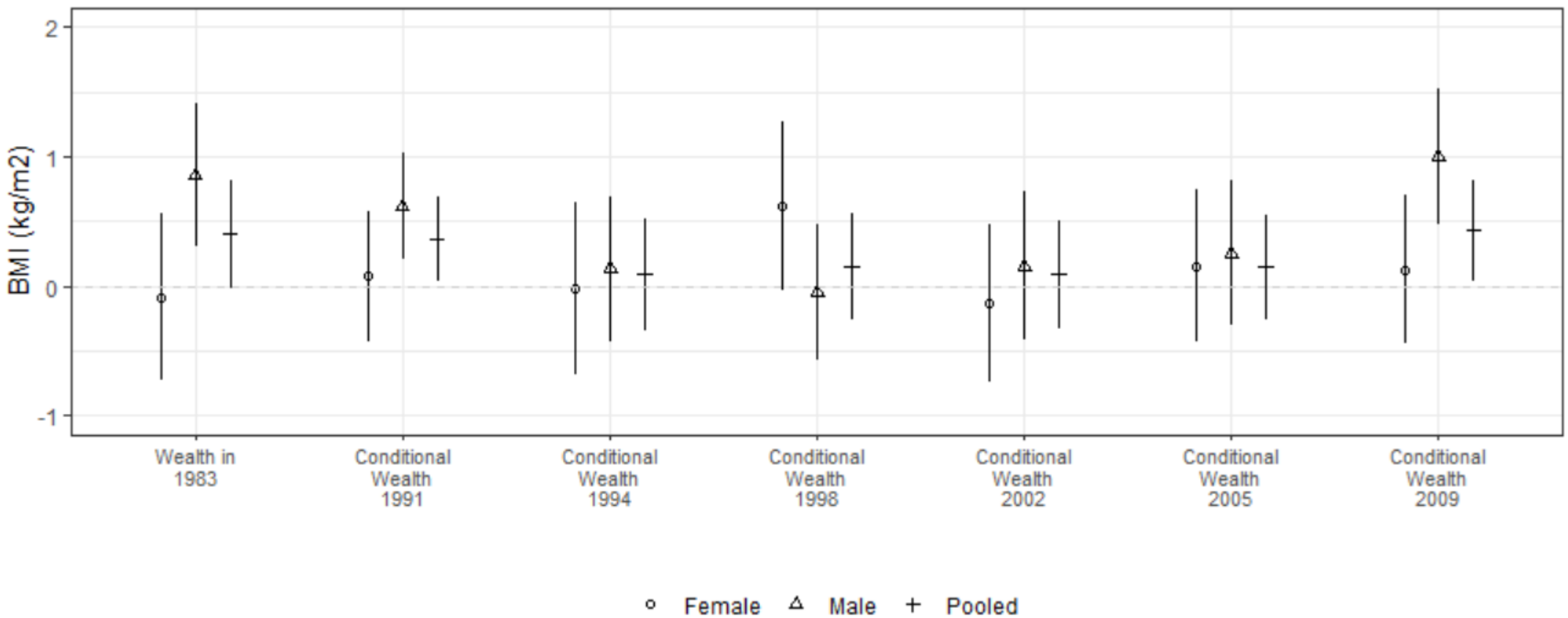
All correlations reported are Pearson correlation coefficients. Figure created using GGally v2.0.0.

Table 5.3 Predictors of conditional wealth for Cebu Longitudinal Health and Nutrition Survey 1983-2009 (n = 1581)

Year	1991	1994	1998	2002	2005	2009
Maternal schooling (y)	0.04 (0.03, 0.05)	0.01 (0, 0.01)	0.01 (0, 0.02)	0 (-0.01, 0.01)	0.01 (0, 0.02)	0 (-0.01, 0.01)
Maternal age (y)	0 (-0.01, 0.01)	-0.01 (-0.01, 0)	0 (-0.01, 0)	0 (-0.01, 0)	0 (-0.01, 0)	0 (0, 0.01)
Birth order	0.02 (-0.02, 0.05)	0.03 (0.01, 0.06)	0.02 (-0.01, 0.04)	0.01 (-0.01, 0.04)	0.01 (-0.02, 0.04)	-0.02 (-0.04, 0.01)
Male	0.02 (-0.04, 0.08)	-0.01 (-0.05, 0.03)	0.09 (0.04, 0.13)	-0.07 (-0.11, -0.02)	0 (-0.04, 0.05)	-0.16 (-0.21, -0.11)
Rural in 1983	0 (-0.19, 0.19)	-0.13 (-0.26, 0.01)	0.08 (-0.07, 0.22)	0.17 (0.03, 0.3)	0.02 (-0.12, 0.17)	0.02 (-0.13, 0.17)
Rural in 1991	-0.20 (-0.39, -0.01)	0.2 (-0.02, 0.43)	-0.24 (-0.48, 0)	-0.26 (-0.49, -0.03)	-0.15 (-0.4, 0.09)	0.15 (-0.09, 0.4)
Rural in 1994		-0.19 (-0.38, 0)	0.17 (-0.06, 0.4)	0.24 (0.02, 0.46)	0.08 (-0.15, 0.31)	0.01 (-0.23, 0.24)
Rural in 1998			0.03 (-0.14, 0.2)	0.01 (-0.18, 0.21)	0.21 (0, 0.42)	-0.1 (-0.32, 0.11)
Rural in 2002				-0.08 (-0.23, 0.08)	0.23 (0.04, 0.42)	0.05 (-0.15, 0.24)
Attained schooling (y)				0.02 (0.02, 0.03)	0.02 (0.01, 0.03)	0.02 (0.01, 0.03)
Rural in 2005					-0.35 (-0.49, -0.21)	0.14 (-0.02, 0.29)
Rural in 2009						-0.20 (-0.31, -0.10)
Formal employment in 2009						0.05 (0.01, 0.10)

Values are displayed estimate and 95% confidence interval from multivariable linear regressions with varying precision reported (all independent variables were entered into the regression in their original units).

Figure 5.4 Pooled and sex-stratified association of conditional wealth with body mass index (kg/m2) in 2009 for Cebu Longitudinal Health and Nutrition Survey 1983-2009 (n = 1503)



Values are estimate and 95% confidence interval from linear regression. All measures (wealth in 1983 and conditional wealth) were in the same units as harmonized wealth. We adjusted for maternal schooling, maternal age, birth order, rural residence (1983 to 2009), attained schooling, and formal employment (in 2009). Pregnant women (n = 77) were excluded from the analysis. BMI missing for one individual (n = 1). Coefficients for all variables are reported in **Supplementary Table 3**.

Supplementary Table 5.1 Comparison of early life characteristics and adult characteristics between those included in analytic sample and those excluded

Variable	N	Original sample (n = 3080)	Analytic sample (n = 1581)	Did not participate in 2009 (n = 1371)	Excluded from complete-case analysis (n = 128)
Maternal schooling (y)	3080	6 (5,9)	6 (5,9)	6 (5,10)	6 (5,9)
Maternal age (y)	3080	25 (22,30)	26 (22,30)	25 (21,30)	26 (22,30)
Birth order	3080	3 (2,4)	3 (2,4)	3 (2,4)	3 (2,4)
Male	3080	53.0%	52.0%	53.9%	55.5%
Rural in 1983	3061	23.6%	27.1%	19.1%	27.3%
Rural in 1991	2264	25.7%	27.0%	21.2%	29.1%
Rural in 1994	2186	26.9%	27.6%	23.8%	29.6%
Rural in 1998	2089	28.3%	28.3%	26.2%	36.4%
Rural in 2002	2023	27.8%	28.5%	25.1%	25.2%
Attained schooling (y)	1786	11 (10,13)	11 (10,13)	11 (9,13)	10 (7,12)
Rural in 2005	1888	29.7%	29.9%	27.6%	31.1%
Pregnant in 2009			N = 77	-	N = 3
Rural in 2009	1708	30.6%	30.4%	-	33.6%
Formal employment in 2009	1903	44.6%	46.7%	-	44.5%
Body mass index in 2009 (kg/m^2)	1885	22.2±3.8	22.4±3.7	21.0±3.6	22.2±3.4
Wealth in 1983	3080	-1.0±0.6	-1.0±0.6	-0.9±0.7	-1.0±0.6
Wealth in 1991	2264	-0.2±0.9	-0.2±0.9	-0.1±0.9	-0.4±0.9
Wealth in 1994	2186	<0.1±0.9	-0.1±0.9	0.0±1.0	-0.2±0.9
Wealth in 1998	2082	0.2±0.9	0.2±0.9	0.3±1.0	0.1±0.8
Wealth in 2002	2015	0.3±0.8	0.2±0.8	0.3±0.8	0.1±0.8
Wealth in 2005	1886	0.5±0.8	0.4±0.8	0.6±0.9	0.3±0.8
Wealth in 2009	1709	0.5±0.8	0.5±0.8	-	0.4±0.8

All values are in mean +- standard deviation or median (25^{th} percentile, 75^{th} percentile) or percentage (%)

Supplementary Table 5.2 Coefficients with varying adjustment for wealth and conditional wealth (n = 1503)

	Intercept	Coefficient for 1983	Coefficient for 1991	Coefficient for 1994	Adjusted R^2
BMI in 2009 ~ Early life covariates up to 1983	20.89 (19.88, 21.9)	-	-	-	0.051
BMI in 2009 ~ Wealth 1983	21.35 (20.12, 22.57)	0.25 (-0.13, 0.64)	-	-	0.051
BMI in 2009 ~ Wealth 1991	21.31 (20.25, 22.37)	-	0.32 (0.05, 0.58)	-	0.055
BMI in 2009 ~ Wealth 1994	21.16 (20.12, 22.19)	-	-	0.28 (0.01, 0.55)	0.053
BMI in 2009 ~ Wealth 1983 + Wealth 1991	21.32 (20.09, 22.55)	0.01 (-0.44, 0.45)	0.32 (0.01, 0.62)	-	0.054
BMI in 2009 ~ Wealth 1983 + Conditional 1991	21.58 (20.33, 22.83)	0.33 (-0.07, 0.73)	0.32 (0.01, 0.62)	-	0.054
BMI in 2009 ~ Wealth 1983 + Wealth 1991 + Wealth 1994	21.3 (20.07, 22.53)	0 (-0.45, 0.45)	0.26 (-0.17, 0.69)	0.08 (-0.35, 0.51)	0.053
BMI in 2009 ~ Wealth 1983 + Conditional 1991 + Conditional 1994	21.58 (20.33, 22.84)	0.34 (-0.07, 0.74)	0.32 (0.01, 0.62)	0.08 (-0.35, 0.51)	0.053
BMI in 2009 ~ Wealth 1983 + Wealth 1991 + Conditional 1994	21.33 (20.1, 22.55)	0.01 (-0.43, 0.46)	0.32 (0.01, 0.62)	0.08 (-0.35, 0.51)	0.053

Values are estimate and 95% confidence interval from linear regression. All measures (wealth in 1983 and conditional wealth) were in the same units as harmonized wealth. We adjusted for maternal schooling, maternal age, birth order, rural residence (up to year in regression). Pregnant women (n = 77) were excluded from the analysis. BMI missing for one individual (n = 1).

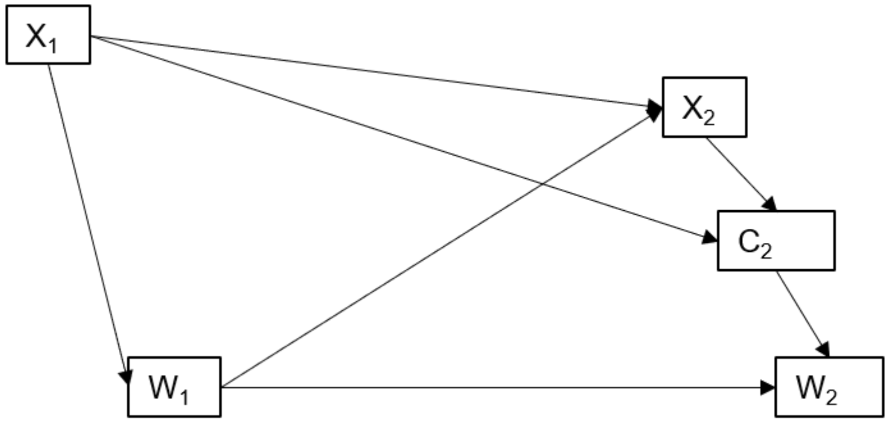
Supplementary Table 5.3 Pooled and sex-stratified association of early life and adult characteristics with body mass index

Variable	Pooled (n = 1503)	Female (n = 682)	Male (n = 821)
Male	1.01 (0.61, 1.4)	-	-
Maternal schooling (y)	0.09 (0.02, 0.17)	0.08 (-0.03, 0.2)	0.10 (0, 0.21)
Maternal age (y)	0.04 (0, 0.08)	0.04 (-0.02, 0.11)	0.04 (-0.02, 0.09)
Birth order	-0.38 (-0.6, -0.16)	-0.44 (-0.76, -0.13)	-0.34 (-0.63, -0.05)
Rural in 1983	0.4 (-0.8, 1.6)	-0.77 (-2.58, 1.04)	1.44 (-0.14, 3.02)
Rural in 1991	-0.53 (-2.5, 1.45)	0.23 (-2.93, 3.4)	-0.67 (-3.16, 1.81)
Rural in 1994	-0.41 (-2.29, 1.47)	-0.12 (-3.14, 2.91)	-0.77 (-3.18, 1.64)
Rural in 1998	-0.62 (-2.34, 1.1)	0.41 (-2.31, 3.14)	-1.81 (-4.11, 0.49)
Rural in 2002	0.41 (-1.17, 1.99)	-1.27 (-3.39, 0.86)	1.94 (-0.45, 4.32)
Attained schooling (y)	-0.03 (-0.1, 0.05)	-0.18 (-0.31, -0.05)	0.05 (-0.05, 0.14)
Rural in 2005	0.1 (-1.13, 1.32)	-0.27 (-1.99, 1.45)	0.16 (-1.59, 1.9)
Rural in 2009	0.4 (-0.47, 1.28)	1.13 (-0.15, 2.41)	-0.19 (-1.39, 1)
Formal employment in 2009	-0.23 (-0.61, 0.15)	-0.64 (-1.23, -0.06)	0.4 (-0.09, 0.89)
Wealth in 1983	0.4 (-0.02, 0.82)	-0.09 (-0.73, 0.55)	0.86 (0.3, 1.41)
Conditional wealth in 1991	0.36 (0.04, 0.68)	0.07 (-0.43, 0.57)	0.62 (0.2, 1.03)
Conditional wealth in 1994	0.09 (-0.34, 0.52)	-0.02 (-0.69, 0.65)	0.13 (-0.43, 0.69)
Conditional wealth in 1998	0.15 (-0.26, 0.56)	0.62 (-0.03, 1.27)	-0.05 (-0.58, 0.48)
Conditional wealth in 2002	0.09 (-0.33, 0.51)	-0.14 (-0.74, 0.47)	0.16 (-0.42, 0.73)
Conditional wealth in 2005	0.15 (-0.26, 0.55)	0.16 (-0.43, 0.74)	0.25 (-0.31, 0.81)

Conditional wealth in 2009	0.43 (0.04, 0.82)	0.12 (-0.45, 0.7)	1.00 (0.47, 1.53)

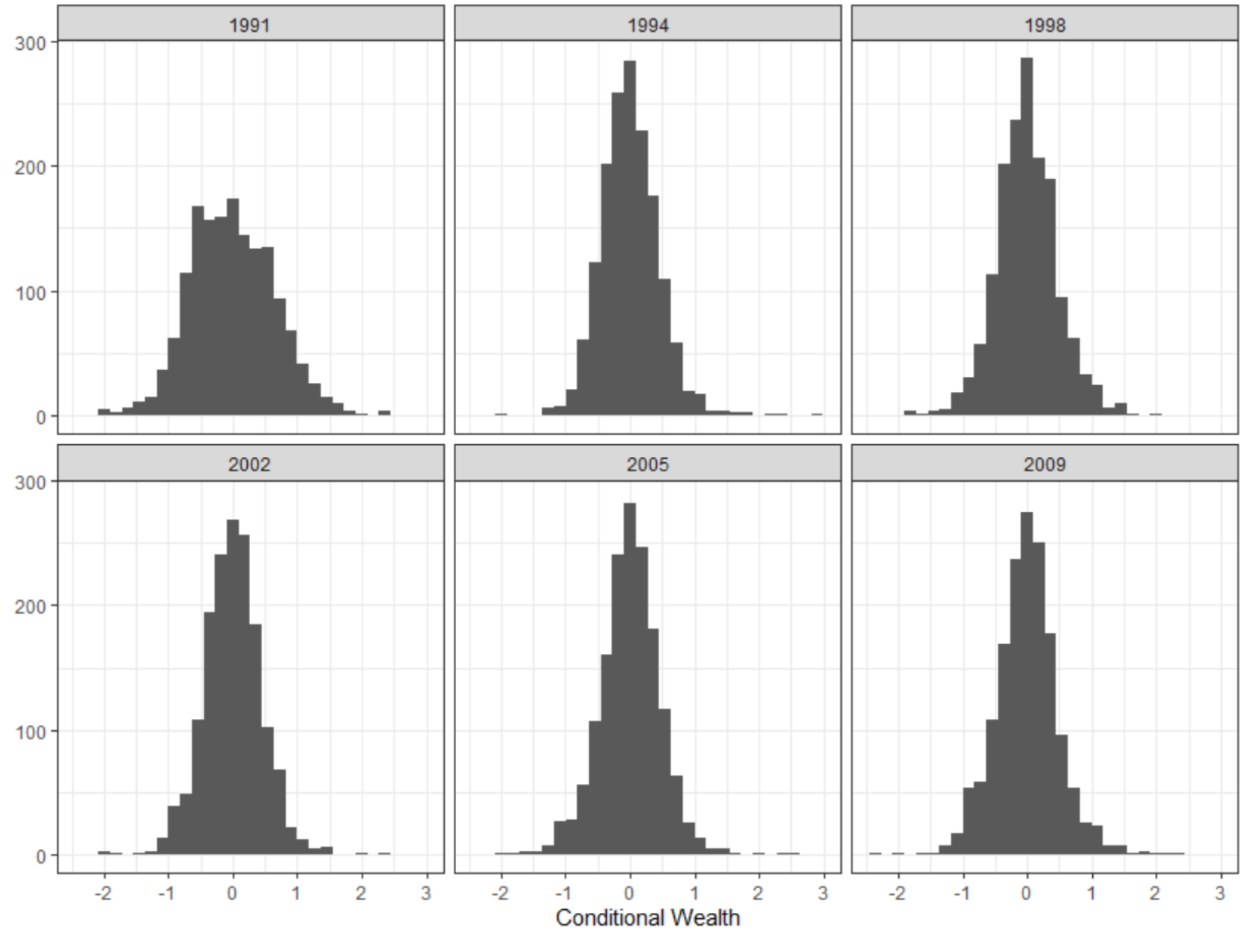
Values are estimate and 95% confidence interval from linear regression. All measures (wealth in 1983 and conditional wealth) were in the same units as harmonized wealth. We adjusted for maternal schooling, maternal age, birth order, rural residence (1983 to 2009), attained schooling, and formal employment (in 2009). Pregnant women (n = 77) were excluded from the analysis. BMI missing for one individual (n = 1).

Supplementary Figure 5.1 Example of bias from adjusting for current measures of wealth while predicting conditional wealth



X_1 and X_2 are covariates associated with wealth (W_1, W_2). C_2 is conditional wealth. Our conditioning set while predicting C_2 consists of X_1 and X_2 only. We define early life wealth (W_1), maternal schooling (X_1) and attained schooling (X_2): $X_1 \rightarrow W_1 \rightarrow X_2$. We do not include W_2 in the conditioning set since W_2 is a linear combination of W_1 and C_2.

Supplementary Figure 5.2 Distribution of conditional wealth at different study waves (n = 1581)



All values are conditional wealth measures derived from complete case analysis of temporally harmonized index.

Chapter 6 Schooling and wealth mobility over the life course in relation to health and human capital in adulthood: an analysis of four birth cohorts from low- and middle-income countries

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Short running head: Life-course socioeconomic position and health

Abbreviations: BMI – Body Mass Index; RPM – Ravens Progressive Matrices; SRQ-20: World Health Organization's Self-Reporting Questionnaire-20; WAIS-IV: Wechsler Adult Intelligence Scale-IV;

Ethics approval and consent to participate: All participants (or their parent, when relevant) provided written informed consent prior to participation at each study wave. Ethical approval for the most recent study wave for the cohorts was obtained from the Federal University of Pelotas, Brazil (Protocol 1.250.366), Institutional Review Board of Emory University, USA (Protocol 95960), Institute of Nutrition for Central America and Panama, Guatemala (Protocol CIE-REV-072-2017), Research Ethics Committee at University of San Carlos, Philippines (Protocol 006/2018-01-borja), and Human Research Ethics Committee at University of Witswatersrand, South Africa (Certificate No. M180225)**.**

Data availability statement: The code for the analysis is available on https://github.com/jvargh7/cohorts-wealth-gains. Data will be available upon reasonable request addressed to the principal investigators at each study site.

ABSTRACT

Background:

Previous research exploring association of wealth and schooling, robust measures of socio-economic position in low- and middle-income countries (LMICs), with health relied on cross-sectional datasets. Our objective was to study the interplay of schooling and wealth mobility over an individual's life course using birth cohorts as well as their association with four domains of health (body mass index, intelligence, psychological distress, wellbeing).

Methods:

We used longitudinal data from birth cohorts in four LMICs (N; Brazil: 4360, Guatemala: 560, Philippines: 1327, South Africa: 1700) and analyzed them separately by cohort. We identified early life and adult predictors of relative wealth mobility during three life stages (school-age: 6-17y, late adolescence: 18-26y and early adulthood: 27-36y). We estimated the association of maternal and own schooling and wealth mobility at different life stages, beyond childhood wealth, with health in adulthood.

Results:

Adult outcomes were measured between 18 and 36 years across the birth cohorts. In all cohorts, maternal schooling and attained schooling were positively associated with relative wealth mobility during school age and later life in all cohorts. Relative wealth mobility in early adulthood was positively associated with BMI in Guatemala and Philippines. In all cohorts, attained schooling and relative wealth mobility at all life stages were independently associated with higher adult intelligence. In Brazil, relative wealth mobility at all life stages were associated with psychological distress and wellbeing. In Philippines and South Africa, psychological distress and wellbeing in early adulthood were associated with relative wealth mobility in early adulthood only, and not with prior measures.

Conclusions:

Maternal and attained schooling are associated with future relative wealth mobility. Across cohorts, relative wealth mobility over the life course was associated with intelligence, while mobility in the most recent period was associated with wellbeing and psychological distress.

KEYWORDS: life course epidemiology, social mobility, wealth, asset index

1 Introduction

Any disease burden in the working-age population (15-64y), who are at their peak health and fitness, have adverse economic consequences for countries (1). Adults under 40 years of age constitute the majority (52%) of the working-age population in low- and middle-income countries (LMIC) (2). However, 17% of disability adjusted life years (DALY) lost from cardiometabolic diseases and 51% of DALYs lost from mental health disorders are in the under-40 age group (3). Changing health behaviors (such as diet, physical activity, smoking, alcohol, sexual behaviors), on account of economic and epidemiological transition, explain some of the observed differences in health status (1, 4).

Socio-economic gradients in health behaviors, stressful life events and health status are visible across populations but evidence from LMICs is scarce (5). The available research on socioeconomic position (SEP) and health among working-age adults in LMICs have three drawbacks. First, they rely primarily on cross-sectional data (6-9). Due to unavailability of prospective life course data, these cross-sectional studies are susceptible to unmeasured confounding and ignore tracking of health status over the life course. Second, most studies explore the role of SEP and its association with one health domain (such as physical health or mental health) with limited transportability of results. Indicators of SEP, such as wealth and schooling, display beneficial associations with many domains of health (10-12). Since studies on the domain of interest may not be available in similar study populations, one is constrained by available studies from unrelated contexts. Research on multiple health domains lend support to the overall benefit of interventions such as mandatory schooling if higher schooling is associated with higher intelligence, lower BMI among women and lower mental distress. Third, any research on SEP that ignores its change over time (social mobility) risks biased results from incorrectly specifying the causal model. Previous research from the United States show how social mobility, beyond average income and income inequality, is associated with mortality, morbidity and health inequities. The reported associations vary by birth cohort, level of baseline SEP and characteristics such as region of residence, and sex (13, 14).

Using prospective life course data on SEP from birth cohorts, our first objective was to study how policy amenable interventions such as higher maternal schooling or attained schooling were associated with future social mobility. Our second objective was to study the association of schooling (maternal, own attained) and social mobility at different stages of the life course with four domains of health (body mass index, cognition, psychological distress, and socio-emotional wellbeing). To address both these objectives, we analyzed data from birth cohorts (birth years:1971 to 1993) from four low- and middle-income countries, in three continents and at different stages of economic development. Consistent findings across cohorts that address limitations of current studies of SEP and health in LMICs, may allow us to generalize our findings related to key life stages and SEP domains that are associated with health.

2 Methods

2.1 Study design and participants

We used data from prospective birth cohorts that are part of the Consortium for Health Oriented Research in Transitioning Societies (COHORTS) collaborative (15). The birth cohorts were from four countries: Brazil (Pelotas Birth Cohort; born 1993), Guatemala (INCAP Longitudinal Study 1969-77; for this analysis we restricted the sample to birth cohort participants born during 1971 to 1975 based on overlap with life stages), Philippines (Cebu Longitudinal Health and Nutrition Study; born 1983-84) and South Africa (Birth to Twenty plus Cohort; born 1990) (16-19). Ethical approval for this secondary analysis was obtained from the Emory University IRB (Protocol 95960). A flow-chart of analytic sample construction for each cohort is available in **Supplementary Fig 6.1**.

2.2 Data collection and variable specification

2.2.1 Life stages

Our categorization of ages into four life stages based on completed age and availability of data were as follows: under 5 (0 to 5y), school age (6 to 17y), late adolescence (18 to 26y) and early adulthood (27 to 36y). The age range considered for late adolescence does not incorporate the current classification of adolescence (10 to 24y), and allowed us to retain additional study participants in our analysis (4).

2.2.2 Socio-economic position

Our main indicators of socio-economic position were schooling and wealth. We included two measures of schooling that were self-reported by mothers at time of enrollment (maternal schooling) and by participants in adulthood (own attained schooling). Wealth is a marker of long-term economic status in societies that are vulnerable to shocks in employment and income. Asset-based indices, a composite of household possession of durable goods and housing characteristics, are commonly used proxies for wealth in LMIC settings that are not vulnerable to transitory shocks in spending, and are associated with non-food expenditures (20).

In order to compare wealth over the life course, we used a previously-created temporally-harmonized asset index derived from a consistently collected set of assets (21). Information on distributional properties of the index (mean, variance/inequality) were reported previously (21). We note that the index remains a measure of relative wealth (positional/rank-based) over time and cannot be interpreted in an absolute sense. We assume that all household assets included are public goods and that people may change households due to transitioning to adulthood or marital status. For individuals with more than one observation within a life stage, we averaged the temporally harmonized asset index for all available data waves in that life stage (**Supplementary Note 6.1**).

We additionally included a measure of whether the participant was formally employed (versus informal employment or unemployment or not seeking work) at the time of data collection. We combined informal employment, unemployed but seeking work and not seeking work into a single category of non-formal employment. However, these categories may be differently associated with the outcomes under consideration, with nuanced implications by sex.

2.2.2 Health outcomes

Data on outcomes were collected in late adolescence (18-26y) in Brazil and South Africa, and in early adulthood (27-36y) in Guatemala, Philippines and South Africa.

Height and weight were measured using standardized protocols in Brazil (in 2015; 22y), Guatemala (in 2002-04; 27-33y), Philippines (in 2017-18; 34-35y) and South Africa (in 2011-12; 22y). We computed the body mass index (BMI) as weight (kg) divided by the square of height (m). We excluded pregnant women in this analysis. Cognition was measured using Wechsler

Adult Intelligence Scale-IV (in 2011; 18y) in Brazil. Cognition was measured using Ravens Progressive matrices (RPM) in Guatemala (in 2002-04; 27-33y), Philippines (in 2017-18; 34-35y) and South Africa (in 2017-18; 27-28y). Psychological distress was measured using World Health Organization's Self-Reporting Questionnaire-20 (SRQ-20) in Brazil (in 2015; 22y), Philippines (in 2017-18; 34-35y) and South Africa (in 2017-18; 27-28y). Wellbeing was measured using Warwick-Edinburgh Wellbeing Scale in Brazil (in 2015; 22y) and using Lyubomrisky's Subjective Happiness Scale in Philippines (in 2017-18; 34-35y) and South Africa (in 2017-18; 27-28y). Since happiness is a form of positive affect, one of the two components of emotional wellbeing (the other being negative affect consisting of shame, fear, guilt etc.), we explored these two scales under the same domain of health.

2.2.3 Early life and adult covariates

Early life covariates (maternal age at birth, birth order of participant and sex of participant) were collected at enrollment for all sites. Additional early-life covariates which are associated with socio-economic position in different countries were also collected at enrollment: maternal skin color and skin color of cohort member for Brazil; year and village of birth for Guatemala; black skin color for South Africa. Skin color is associated with prejudice in many cultures and may moderate the pathway from early life circumstances to adult wealth. We included adult covariates measured concurrently with the outcomes: whether participants have children (yes/no), marital status (married/co-habiting versus not) and rural residence (for Guatemala and Philippines).

2.3 Statistical Analysis

We restricted our analytic sample to individuals who provided data for health outcomes in adulthood (sample size varies by outcome; **Table 6.1**) We mean standardized all outcomes (except BMI) to unit variance within each cohort to allow us to visually represent associations across similar constructs between cohorts. We do not statistically compare these associations given the different contexts of these cohorts.

2.3.1 Conditional wealth for relative wealth mobility

We used relative change in wealth as a marker of social mobility. Such mobility could be due to an individual gaining or losing wealth from differently utilizing human capital, migrating to a different household (changes in employment, marital status or transitioning to adulthood) and random life events (such as winning a lottery or stressful experiences). We derived conditional wealth scores to model relative wealth mobility between consecutive life stages that was independent of previous wealth measures (22). Conditional wealth is created by regressing the harmonized index measure at each study wave on all prior harmonized asset index measures for each participant and extracting the residuals for each imputed dataset. For conditional wealth at time T, we use all measures of wealth from t = 1 to t = T-1 as predictors. To account for missingness, we used multiple imputation (10 datasets, 50 iterations) with auxiliary covariates (early life covariates, adult covariates of socio-economic position) assuming missing at random.

$$\text{Conditional Wealth}_{i,T} = \text{Wealth}_{i,T} - \widehat{\text{Wealth}}_{i,T} = \text{Wealth}_{i,T} - \left[b_0 + \sum_{t=1}^{t=T-1} b_t \ \text{Wealth}_{i,t}\right] \quad \textbf{[1]}$$

In the subsequent statistical analysis, we refer to wealth in childhood as ‘early life wealth’ and conditional wealth at different life stages as ‘relative wealth mobility’ for that life stage.

2.3.2 Predictors of future relative wealth mobility

We used multivariable linear regression with robust standard errors to study the association of early life characteristics and maternal schooling with relative wealth mobility in school age. For relative wealth mobility in emerging and early adulthood, we additionally estimated the association of attained schooling and its heterogeneity by sex to assess if there were differential returns for schooling, after adjusting for other early and adult life covariates.

$$\text{Relative wealth mobility}_{T} = c_0 + c_1 \text{ Maternal Schooling} + c_2 \text{ Own Schooling*I(Age} \geq 18) + c_3 \text{ Formal Employment*I(Age} \geq 18) + c_4 \text{ Sex} + c_5 \text{ Own Schooling*I(Age} \geq 18)\text{*Sex} + d\,X \qquad \textbf{[2]}$$

where I (Age ≥18) is equal to one if age is greater than or equal to 18 or zero if age is less than 18 (i.e. school-age) and X are early life covariates or covariates preceding the life stage. We computed coefficients and standard errors as per combining rules for imputed datasets.

2.3.3 Association of schooling and wealth with health outcomes in adulthood

We used multivariable linear regression with robust standard errors to study the association of schooling, early life wealth and relative wealth mobility with health in adulthood. We adjusted for early life and adult covariates. Since relative wealth mobility measures are in the same units as early life wealth, we were able to assess the relative importance of life stages for health and human capital at time T.

$$\text{Adult outcome}_{T} = e_0 + e_1 \text{ Early Life Wealth} + \sum_{t=2}^{t=T} e_t \text{ Relative Mobility}_t + f_1 \text{ Maternal Schooling} + f_2 \text{ Own Schooling} + f_3 \text{ Formal Employment} + g\,Z \qquad \textbf{[3]}$$

where Z are early life covariates or covariates preceding time T that are confounders of the relative mobility and adult outcome association. We repeated the analysis after exploring effect modification of association of outcomes with early life wealth and relative wealth mobility by sex for Brazil, Philippines and South Africa after adjusting for other covariates.

2.4 Sensitivity Analysis for non-participation

We assessed if participation status in adulthood could have biased our observed association of life course SEP with health by repeating our analysis with inverse probability of censoring weights for non-participation due to death or non-response. Additional details for the analysis are available in **Supplementary Note 6.2**.

We adjusted for clustering by maternal identifier in Guatemala, and current residence (barangay) in Philippines. All analysis was carried out using R 3.6.1 using mice v3.13.0. The code for the analysis is available at https://github.com/jvargh7/cohorts-wealth-gains.

3 Results

3.1 Descriptive characteristics and trends

Cohort members experienced intergenerational educational mobility, attaining more schooling than their mothers (**Table 6.1**). Early life characteristics of cohort members did not differ between participants retained in follow-up and participants who died or did not respond (**Supplementary Table 6.1 to 6.4**) in adulthood. Household wealth increased across all cohorts suggesting improved standards of living over time (**Fig 6.2**). Visual inspection of relative wealth mobility (that did not incorporate between-imputation variance), given the similar variance in wealth, suggests relative wealth mobility at different life stages was not restricted to few households (**Supplementary Fig 6.1**). The distribution of relative wealth mobility around the median was symmetric across life stages in all cohorts except South Africa in late adolescence and early adulthood (**Table 6.2**). Magnitude of relative wealth mobility was highest in Brazil during late adolescence (52.8%), in Guatemala during school-age (73.1%), in Philippines during school-age (48.9%) and early adulthood (48.4%), and similar across life stages in South Africa.

3.2 Association of schooling with future relative wealth mobility

We display the association of early life characteristics with relative wealth mobility in school-age, late adolescence and early adulthood in **Table 6.3**. Maternal schooling was positively associated with relative mobility in school-age for all cohorts. Own attained schooling was positively associated with relative wealth mobility in all cohorts in both late adolescence and early adulthood. We observed suggestive evidence of lower returns for males, relative to females for attained schooling in Brazil and Philippines during late adolescence. We did not identify any predictors of relative wealth mobility during late adolescence in South Africa. Cross-sectional formal employment was associated with relative wealth mobility in early adulthood in Philippines and South Africa, but not in Guatemala.

3.3 Association of life course socio-economic position with health

We display associations of life course wealth and schooling with health outcomes in adulthood in **Fig 6.2** and **Table 6.4**.

3.3.1 Body mass index

BMI was not associated with maternal schooling or own attained schooling for any cohort after adjusting for other covariates except in South Africa (0.13 kg/m^2 per year). Wealth in childhood was not associated with BMI in adulthood in Brazil, Guatemala and South Africa but was positively associated in Philippines (0.97 kg/m^2 per 1 unit). Relative wealth mobility in school-age, and late adolescence were not associated with BMI in Brazil, Guatemala and South Africa. However, relative wealth mobility in school-age was positively associated with BMI (0.67 kg/m^2 per 1 unit, 95%CI: 0.16, 1.17) in Philippines and not associated in late adolescence (0.39 kg/m^2 per 1 unit, 95%CI: -0.29, 1.07). Relative wealth mobility during early adulthood was positively associated with BMI in Philippines and Guatemala. Formal employment was positively associated with BMI in Philippines (0.41 kg/m^2, 95%CI: -0.09, 0.90) but not associated in Brazil and Guatemala.

3.3.2 Intelligence

Intelligence was measured in late adolescence for Brazil and in early adulthood for other cohorts. Both maternal schooling (0.02 to 0.05 z-scores per 1 year) and attained schooling (0.11 to 0.20 z-scores per 1 year) were positively associated with intelligence in Guatemala, Philippines and South Africa. We did not adjust for attained schooling in Brazil since data was collected at 18y and many cohort members were still in school. Intelligence in Brazil was associated with wealth in childhood (0.22 z-scores per 1 unit; 95% CI: 0.18,0.25), relative wealth mobility in school age (0.26 z-scores per 1 unit; 95% CI:0.21, 0.31) and relative wealth mobility in late adolescence (0.13 z-scores per 1 unit; 95% CI:0.08, 0.19). Similarly, intelligence (in z-scores) was positively associated with wealth in childhood (except in Guatemala) and relative wealth mobility at all life stages in Guatemala, Philippines and South Africa. Formal employment was positively associated with intelligence in Philippines and South Africa, but not in Guatemala.

3.3.3 Psychological distress

Psychological distress was measured using WHO SRQ-20 in Brazil, Philippines and South Africa. Maternal schooling and wealth in childhood were not associated with psychological distress in Brazil, Philippines and South Africa. In Brazil, relative wealth mobility in school-age (-0.08 z-scores per 1 unit) and late adolescence (-0.14 z-scores per 1 unit) were negatively associated with psychological distress, but were not associated in Philippines and South Africa. Relative mobility in early adulthood was negatively associated with psychological distress in Philippines (-0.11 z-scores per 1 unit) and South Africa (-0.11 z-scores per 1 unit). Attained schooling (1 year increase) was negatively associated with psychological distress (in z-scores) in Brazil (-0.04; 95% CI:-0.06,-0.02), and South Africa (-0.05, 95%CI: -0.08, -0.01) but not in Philippines. Formal employment was negatively associated with psychological distress in Brazil (-0.11 z-scores, 95%CI: -0.18, -0.04) and Philippines (-0.09 z-scores, 95%CI: -0.03, 0.20) but not South Africa.

3.3.4 Wellbeing

Wellbeing was measured in late adolescence in Brazil and in early adulthood in Philippines and South Africa. Maternal schooling was not associated with wellbeing in any cohort. Attained schooling was positively associated with wellbeing in Brazil (0.07, 95%CI: 0.05, 0.08), but not in Philippines or South Africa. Wealth in childhood was positively associated with wellbeing (in z-scores) in Brazil (0.06 z-scores per 1 unit) and Philippines (0.07 z-scores per 1 unit) but negatively associated in South Africa (-0.08 z-scores per 1 unit). Relative wealth mobility in school age was positively associated with wellbeing in Brazil (0.10 z-scores per 1 unit) and South Africa (0.06 z-scores per 1 unit). Relative wealth mobility in late adolescence was positively associated with wellbeing in Brazil (0.22 z-scores per 1 unit) but not in Philippines and South Africa. Relative wealth mobility in early adulthood was positively associated with wellbeing in Philippines (0.21 z-scores per 1 unit) and South Africa (0.08 z-scores per 1 unit). Attained schooling was positively associated with wellbeing in Brazil (0.07 z-scores per 1 unit) but not in Philippines and South Africa. Formal employment was associated with wellbeing in Brazil (0.18 z-scores per 1 unit), Philippines (0.11 z-scores per 1 unit) and South Africa (0.08 z-scores per 1 unit).

3.4 Association of wealth with health outcomes by sex

Descriptive statistics by sex were provided in **Supplementary Tables 6.5** and **6.6.** Associations of wealth in childhood and relative wealth mobility over the life course were similar by sex for IQ, psychological distress and wellbeing (**Supplementary Fig 6.2, Supplementary Table 6.7**). However, in Brazil, Philippines and South Africa, we observed potential heterogeneity by sex in association by childhood wealth and relative wealth mobility in school-age, late adolescence and early adulthood (for Philippines) with BMI.

3.5 Sensitivity analysis for non-participation

Our results (**Supplementary Fig 6.3**) after weighting for non-participation (due to death or non-response) were similar to the unweighted results for all associations. A detailed summary of results is available in **Supplementary Table 6.8**.

4 Discussion

Temporally harmonized asset indices allow us to measure wealth in the same scale over the life course. Maternal and own attained schooling predicted future relative wealth mobility in school age (6 to 17y) and beyond (18 to 36y). In our study, childhood wealth was not the sole sensitive period (i.e. the only life stage that was strongly associated), after adjusting for later life measures of relative wealth mobility- suggesting a potential for safety nets beyond this important life stage. Our results did not show consistent findings for BMI across cohorts. However, wealth mobility over the life course as well as schooling was predictive of intelligence in all cohorts. Upward wealth mobility between late adolescence and early adulthood was associated with lower psychological distress and higher happiness in Philippines and South Africa.

The association of schooling (or its surrogates) with relative mobility in adulthood among peers (households) may be associated with better utilization of capital, better social networks and eligibility for higher wages or employment. Evidence from natural experiments, such as mandatory schooling policies, which have led to higher attained schooling, showed improvements in IQ (11). For example, increasing the years of compulsory schooling from 7 to 9 years in Norway, show that a 1 year increase in schooling is associated with 3.7 point increase in adolescent IQ (23). A review of conditional cash transfers, mostly from Latin America, targeting school enrollment have led to higher attained schooling and higher cognitive skills with mixed evidence of benefit for learning outcomes and labor market participation. However, the authors remark that these mixed results may be due to lower duration of follow-up and unobserved market forces in LMICs as well as methodological challenges facing long term evaluations of the interventions (24). Our research thus suggests cumulative advantage in IQ from investments in childhood and school age, consistent with previous research (25, 26). The observed associations with IQ maybe explained by reverse causality such that those who experienced relative wealth mobility, beyond the cohort on average, may have done so due to different IQ levels (27).

Our results that suggest adult BMI is a function of life course wealth and that the obesity transition framework independently does not capture the nuances of age-period-cohort effects and social mobility in LMICs. For example, under the same level of economic development and assumptions of no country-level heterogeneity, the prevalence of overweight and obesity may be higher among the rich in older cohorts and higher among the poor in younger cohorts, consistent with studies on the persistence of overweight over the life course (28, 29). Moreover, SEP in other life stages, beyond current SEP, may be associated with BMI. The differential associations reported for BMI with mobility in school-age and late adolescence may be a result of unmeasured period and cohort effects across countries (30-32). Examples of such effects may include increased affordability of processed foods or economic shocks at the household level leading to food insecurity. The heterogeneity by sex in Brazil, Philippines and South Africa for the association of BMI with relative wealth mobility are consistent with other studies from LMICs that show negative associations of SEP with BMI among women (12).

Economic shocks from loss of employment or income may cause psychological distress as observed in our study, while gains in wealth may improve life satisfaction and wellbeing (33-35). Our results from Brazil are consistent with on research from high-income countries that suggest psychological distress and wellbeing in late adolescence is associated with wealth in childhood and in adolescence (36, 37). We did not observe heterogeneity by sex in any cohort for psychological distress and wellbeing.

Despite strengths such as harmonized measures of SEP across cohorts, long duration of follow-up and consistently collected outcomes, our analysis has limitations. Firstly, although the cohorts were community based, they are not representative of the countries and their constituent populations. Furthermore, all cohorts experienced varying degrees of attrition. Though our sensitivity analysis suggested that results did not change on accounting for non-participation, it was limited by availability of early life covariates that could sufficiently predict attrition. Second, our framework explored the importance of life stages of changes in relative wealth, as measured by a temporally harmonized asset index, beyond the cohort trajectory. We did not explore how individual components may be associated with health in our analysis and alternate pathways of association of SEP with health such as psychosocial support from social networks (38). Moreover, the harmonized asset index assumes a similar structure of interrelationships between assets that may not be plausible under all circumstances. However, we have previously shown that the asset index constructed from a limited set of assets was correlated with cross-sectional indices routinely constructed in LMIC research (21). Finally, our results are unable to distinguish the direction of causality from SEP to health. A previous systematic review of research from high income countries (34 studies, ages 7-90y) suggests a lack of clarity on the relative importance of social causation (SEP determines health) and health selection (health determines SEP) in adulthood (39).

Maternal schooling and own attained schooling predicted future wealth mobility over the life course four birth cohorts. Upward relative wealth mobility was associated with higher intelligence as well as better mental health and socio-emotional wellbeing. Although we may not be able to intervene on wealth mobility directly, social safety nets such as mandatory schooling and universal mental health coverage may offset the resulting disease burden from social persistence or downward mobility.

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Research in Context

Evidence before this study

We searched Medline through PubMed with the search terms ((((("2000/01/01"[Date - Publication] : "2021/10/01"[Date - Publication])) AND (life course[Title/Abstract])) AND (socio-economic position[Title/Abstract] OR socio-economic status[Title/Abstract] OR wealth[Title/Abstract] OR education[Title/Abstract] OR employment[Title/Abstract])) AND (body mass index[Title/Abstract] OR mental health[Title/Abstract] OR psychological distress[Title/Abstract] OR happiness[Title/Abstract] OR wellbeing[Title/Abstract] OR cognition[Title/Abstract] OR intelligence[Title/Abstract])) AND (low-income[Title/Abstract] OR LMIC[Title/Abstract] OR middle-income[Title/Abstract] OR lower middle-income[Title/Abstract]) for manuscripts published in any language between Jan 1, 2000 and Oct 1, 2021. Our search yielded 15 articles (**Supplementary Note 6.3**). Most of the reviewed research from LMICs report associations between cross-sectional socio-economic position and health. Longitudinal studies such as the Young Lives cohort explored the role of SEP with adolescent outcomes but not outcomes in early adulthood. We additionally reviewed studies from international collaborations (such as NCD-RisC, PURE cohort), systematic reviews and comparative analysis of cross-sectional surveys (such as MICS, WHO-SAGE, Demographic and Health Surveys) for a comprehensive perspective on the role of SEP on health in LMICs (**Supplementary Note 6.4**).

Evidence from high-income countries suggest that early life investments and social safety nets throughout the life course are protective for health. However, there was inadequate evidence on the role of different indicators of SEP and their relative importance over the life course for cognition, physical, mental and socio-emotional wellbeing in adulthood since most studies were either cross-sectional or included a limited set of SEP indicators. Our study aimed to quantify the role of schooling and life course wealth on health and human capital in late adolescence and early adulthood.

Added value of this study

This study provides the most comprehensive picture of how life course socio-economic position is associated with health and human capital among adults in LMICs. Maternal and attained schooling were associated with changes in relative wealth over the life course for all cohorts. Wealth in childhood was not solely associated with BMI, intelligence, psychological distress or wellbeing. We did not observe consistent associations of SEP with BMI in adulthood across cohorts with different life stages being associated in different cohorts. Life course SEP was positively associated with adult intelligence across all cohorts, suggesting a cumulative advantage from higher relative position at all life stages. Alternately, our results could suggest reverse causality by early-life intelligence. Recent upward wealth mobility were consistently associated with improved mental health and wellbeing in all cohorts. We did not observe heterogeneity by sex in the associations of life course SEP with intelligence, psychological distress or wellbeing.

Implications of all the available evidence

Our results suggest a need for safety nets beyond childhood and school age. Interventions such as mandatory schooling and universal mental health coverage may be beneficial for reducing the physical and psychological toll of economic shocks from slowing economic growth and wealth inequality.

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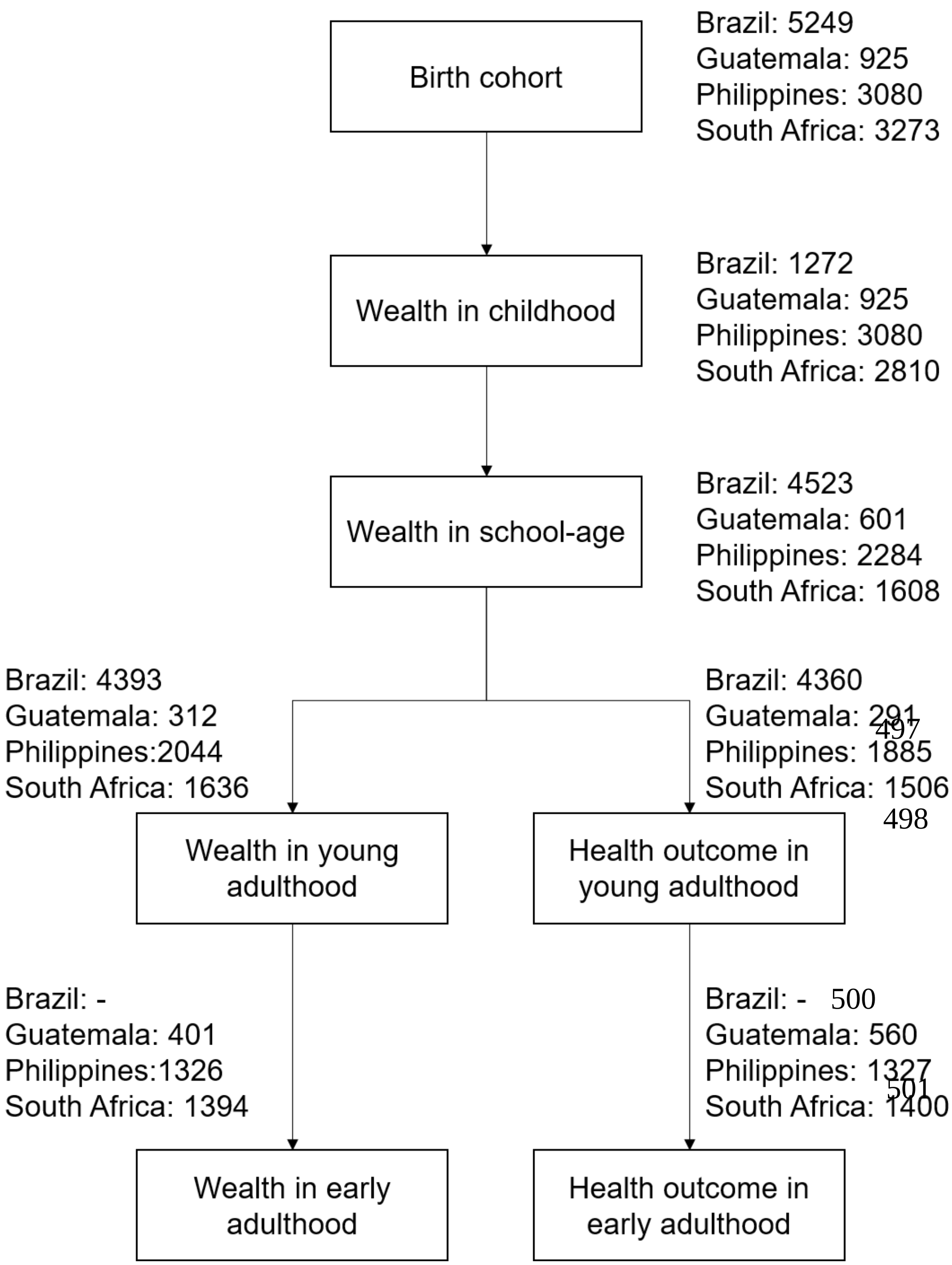
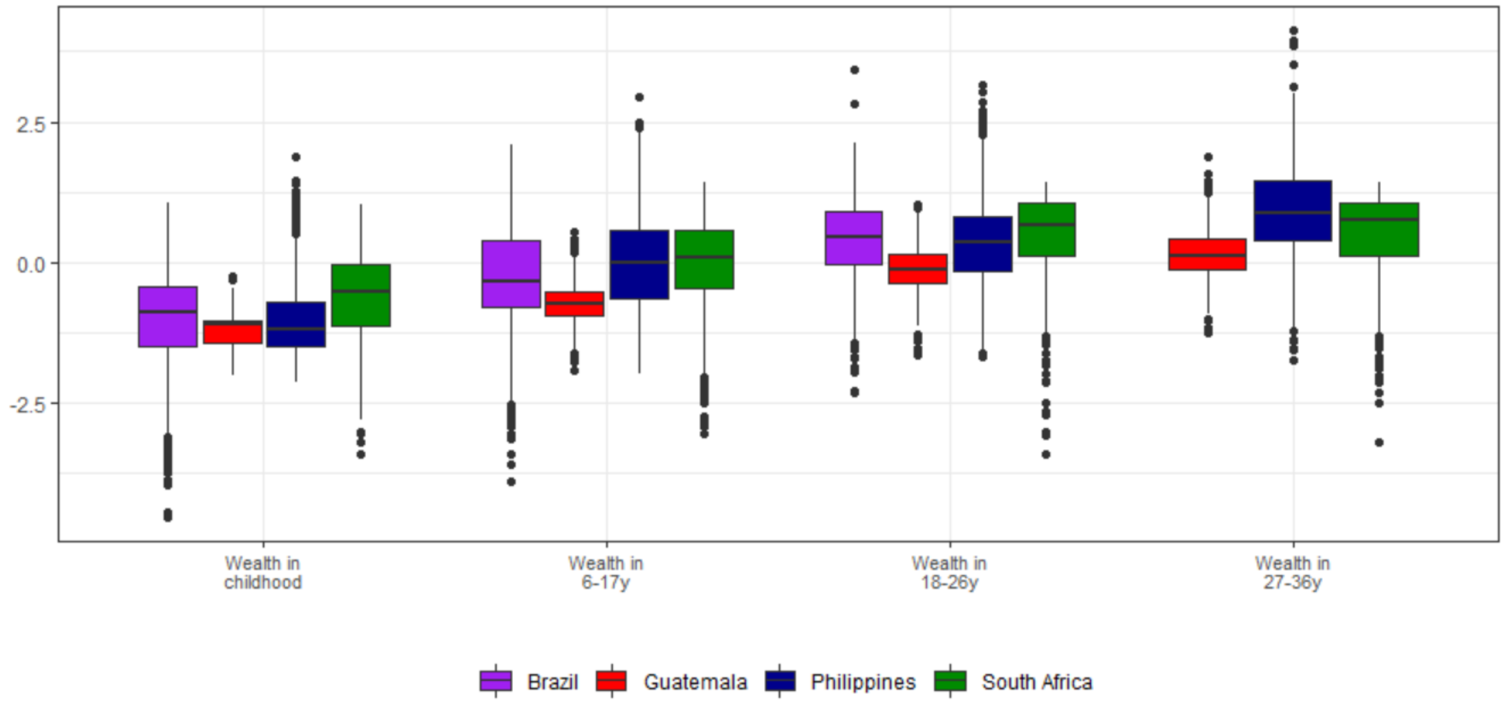
Figure 6.1 Flow chart for participation for the birth cohorts



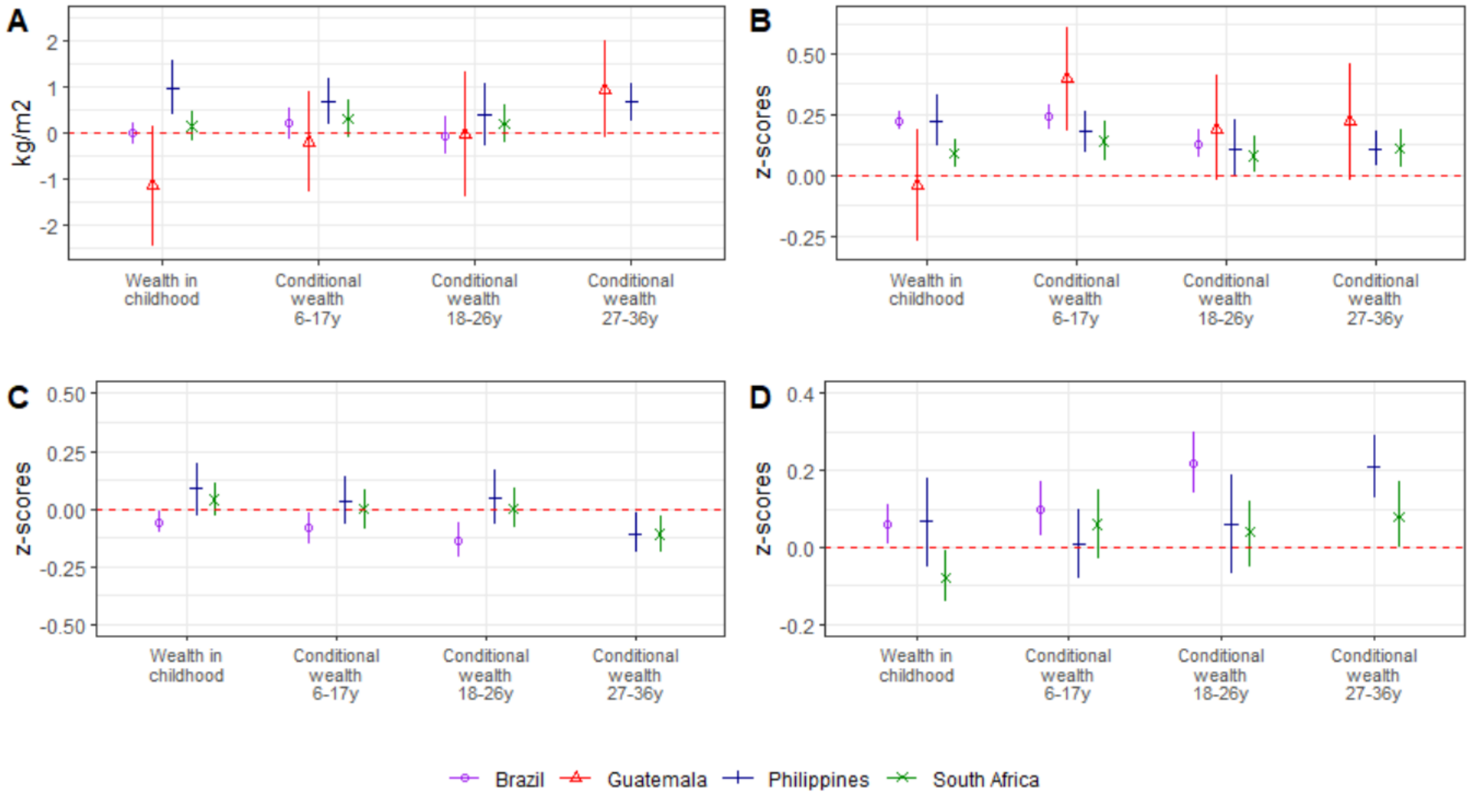
INCAP cohort (Guatemala; 1969-77) consisted of 2392 members, of whom those born between 1971 and 1975 are included in the analytic sample.

Figure 6.2 Distribution of life-course wealth in four birth cohorts



Wealth measures are derived from a temporally harmonized asset index based on household possession of consistently collected assets and housing characteristics. Displayed values are averaged across 10 imputed datasets for all participants who reported any outcome in adulthood (18-36y). Values of the index cannot be compared between birth cohorts.

Figure 6.3 Association of life course socio-economic position with health and human capital in adulthood (18-36y)



Values reported are regression coefficients and 95% robust confidence intervals. A: BMI in kg/m^2, B: Intelligence in z-scores, C: Psychological distress (Perceived Stress Scale, SRQ-20) in z-scores, D: Wellbeing in z-scores; regressions were adjusted for early life covariates (maternal schooling, maternal age, birth order, sex), rural residence, whether they are married and whether they have children. Coefficients for schooling and employment are provided in **Table 6.4**.

Table 6.1 Characteristics of participants in four birth cohorts across the life course

	Brazil (Pelotas 1993)[a] n = 4360		Guatemala (INCAP)[b] n = 560		Philippines (CLHNS)[c] n = 1327		South Africa (Birth to Twenty plus)[d] n = 1700	
	N	**Summary**	**N**	**Summary**	**N**	**Summary**	**N**	**Summary**
Early life covariates								
Maternal schooling (years)_	4353	6.0 [4.0,9.0]	555	1.0 [0.0,2.0]	1327	6.0 [5.0,9.0]	1577	9 [9, 12]
Maternal age (years)	4359	26.0±6.4	556	26.8±7.1	1327	26.6±6.2	1698	25.8±6.2
Maternal skin color (= white)	4358	76.8%	-	-	-	-	1700	
Birth order	4360	2 [1, 3]	554	4.0 [2.0,4.0]	1327	3.0 [2.0,4.0]	1668	2 [1,3]
Male sex	4360	48.4%	560	47.5%	1327	53.9%	1700	48.4%
Atole supplementation	-	-	560	51.4%	-	-	-	-
Exposure to supplementation in first 1000 days	-	-	560	86.6%	-	-	-	-
Skin color (= white)	4083	59.8%	-	-	-	-		
Skin color (= black)	-	-	-	-	-	-	1700	88.4%
Adult covariates [e]								
Formal employment	3802	34.2%	460	42.4%	1326	35.0%	1371	35.1%
Attained schooling (years)	3797	11 [8, 12]	552	6 [2, 6]	1327	11 [9.5, 13]	1668	12 [10,12]
Married	3802	39.7%	524	78.6%	1326	46.6%	1359	10.8%
Currently pregnant[f]		55		18		26		0
Have children	4355	25.8%	523	100%	1326	82.7%	1400	43.2%
Rural residence	-	-	560	73.9%	1326	33.6%	-	-
Health outcomes								
Body Mass Index (kg/m^2)	3561	25.2±5.3	480	25.5±4.1	1293	25.0±4.7	1506	23.6±5.5
Wechsler Adult Intelligence Scale –IV (WAIS-IV)	4049	97 [88,105]	-	-	-	-	-	-
Ravens Progressive Matrices			544	17 [14,22]	1327	32 [23,41]	1396	39 [32,44]
SRQ-20	3784	3 [1,6]	-	-	1326	2 [0,4]	1399	6 [3,10]

Warwick-Edinburgh Mental Well-being Scale (WEMWS)	3515	53 [46,58]	-	-	-	-	-	-
Subjective Happiness Scale	-	-	-	-	1326	3.5 [3.2,4.0]	1397	4.0 [3.0,5.0]

Descriptive statistics are presented for those who reported any outcome in adulthood (18-36y). Continuous variables were summarized as mean ± standard deviation or Median [25th percentile, 75th percentile]. Categorical variables were summarized as N or percentage (%).

a Pelotas 1993 birth cohort collected outcome data in emerging adulthood: in 2011 (age 18: WAIS-IV) and 2015 (age 22: BMI, SRQ-20, WEMWS)

b Only those members of the INCAP birth cohort who were born after 1971 and were in the appropriate age ranges at study waves during which asset data was collected were included; data on pregnancy in adulthood available only for those who were in original study villages during 1996-99.

c Only singleton births (n = 3080) for CLHNS were included.

d Birth to Twenty plus cohort collected BMI in emerging adulthood (in 2012, age 22) and other outcomes in early adulthood (in 2017-18, age 27-28)

e All covariates measured at same time as outcome (except for WAIS-IV in Brazil and BMI in South Africa)

f Number of female participants

Table 6.2 Summary of early life wealth and relative wealth mobility in four birth cohorts across the life course

	Brazil	**Guatemala**	**Philippines**	**South Africa**
***Mean* ± *SD*[a]**				
Wealth in childhood	-0.99 ± 0.95	-1.22 ± 0.31	-1.04 ± 0.63	-0.58 ± 0.85
Relative wealth mobility in school-age	0 ± 0.53	0 ± 0.33	0 ± 0.6	0 ± 0.66
Relative wealth mobility in late adolescence	0 ± 0.48	0 ± 0.3	0 ± 0.43	0 ± 0.66
Relative wealth mobility in early adulthood		0 ± 0.32	0 ± 0.56	0 ± 0.64
***Median (25%ile, 75%ile)* [a]**				
Wealth in childhood	-0.91 [-1.48, -0.42]	-1.11 [-1.44, -1.03]	-1.19 [-1.5, -0.7]	-0.52 [-1.13, -0.03]
Relative wealth mobility in school-age	-0.03 [-0.34, 0.37]	-0.02 [-0.2, 0.17]	-0.01 [-0.45, 0.42]	0.04 [-0.4, 0.44]
Relative wealth mobility in late adolescence	0.03 [-0.29, 0.31]	0.03 [-0.16, 0.17]	-0.01 [-0.29, 0.28]	0.12 [-0.22, 0.38]
Relative wealth mobility in early adulthood		-0.02 [-0.2, 0.18]	-0.01 [-0.31, 0.31]	0.1 [-0.27, 0.41]
***Average between imputation standard deviation*[b]**				
Wealth in childhood	0.65	0	0	0.25
Relative wealth mobility in school-age	0.38	0.13	0	0.2
Relative wealth mobility in late adolescence	0.08	0.25	0.01	0.16
Relative wealth mobility in early adulthood		0.27	0.36	0.32
***Magnitude of relative mobility* [c]**				
Relative wealth mobility in school-age	32.68	72.66	48.94	75.72
Relative wealth mobility in late adolescence	52.82	56.02	33.58	69.77
Relative wealth mobility in early adulthood		50.54	48.37	71.72

[a] Summary of average of wealth or conditional wealth across all imputed datasets. Standard deviation is square root of average within-imputed data variance for wealth or conditional wealth.

[b] Square root of average between imputed data variance at an individual level

[c] Share of cross-sectional variance is an indicator of magnitude of relative wealth mobility experienced within the analytic sample between consecutive time points. The quantity was calculated as percentage of variance in cross-sectional wealth that is between imputed data variance in conditional wealth.

Table 6.3 Association with conditional wealth in four birth cohorts across the life course

	Brazil (Pelotas 1993)	Guatemala (INCAP)	Philippines (CLHNS)	South Africa (Birth to Twenty plus)
	n = 4360	**n = 560**	**n = 1327**	**n = 1700**
School-age (6 to 17y)				
Maternal schooling (years)	0.05 (0.04, 0.06)	0.04 (0.02, 0.06)	0.04 (0.03, 0.05)	0.01 (0, 0.03)
Male	0.06 (0.01, 0.11)	-0.02 (-0.09, 0.05)	0.05 (-0.01, 0.11)	-0.02 (-0.09, 0.05)
Birth order	0.00 (-0.03, 0.04)	0.04 (-0.01, 0.08)	0.05 (0.02, 0.09)	0 (-0.05, 0.05)
Rural residence in school-age	-	-	-0.15 (-0.22, -0.08)	-
Late adolescence (18 to 26y)				
Maternal schooling (years)	0 (-0.01, 0)	0 (-0.03, 0.03)	0 (-0.01, 0.01)	0.01 (0, 0.02)
Male	0.12 (0.09, 0.15)	0.05 (-0.07, 0.16)	-0.06 (-0.11, -0.02)	-0.01 (-0.08, 0.05)
Birth order	0 (-0.02, 0.02)	-0.02 (-0.08, 0.03)	0.01 (-0.02, 0.03)	0 (-0.05, 0.05)
Attained schooling (years)	0.04 (0.03, 0.05)	0.02 (0, 0.04)	0.04 (0.03, 0.05)	0.02 (-0.01, 0.05)
Attained schooling x Male	-0.02 (-0.03, 0.00)	0 (-0.02, 0.02)	-0.01 (-0.03, 0.00)	-0.01 (-0.06, 0.03)
Rural residence in late adolescence	-	-0.09 (-0.28, 0.1)	0.10 (0.05, 0.15)	-
Formal employment in late adolescence	0.02 (-0.02, 0.05)	-	0.05 (-0.01, 0.11)	-
Early adulthood (27 to 36y)				
Maternal schooling (years)	-	0.03 (0, 0.06)	-0.01 (-0.02, 0.00)	0.02 (0, 0.04)

Male	-	-0.08 (-0.2, 0.04)	0.03 (-0.04, 0.10)	-0.13 (-0.20, -0.05)
Birth order	-	0.01 (-0.04, 0.06)	-0.03 (-0.07, 0.01)	-0.02 (-0.07, 0.04)
Attained schooling (years)	-	0.02 (0, 0.04)	0.03 (0.02, 0.05)	0.03 (-0.01, 0.07)
Attained schooling x Male		0 (-0.02, 0.02)	0.01 (-0.01, 0.03)	0.04 (-0.01, 0.09)
Rural residence in early adulthood	-	0.06 (-0.36, 0.48)	0.15 (0.06, 0.23)	-
Formal employment in early adulthood	-	0.01 (-0.12, 0.14)	0.06 (-0.01, 0.13)	0.12 (0.04, 0.20)

Values reported are regression coefficients and 95% robust confidence intervals after adjusting for early life and adult characteristics. Conditional wealth measures (in same units as temporally harmonized asset index) were computed on the imputed dataset among those who provided data on any outcome in either young or early adulthood. Conditional wealth measures were uncorrelated with previous measures of wealth by their nature of construction and are a measure of relative wealth mobility. The coefficients displayed were therefore adjusted for wealth in earlier life stages. Associations above were displayed for analytic sample at each life stage after adjusting for cohort-specific early life characteristics in school-age, and additionally in adulthood for whether they are married, have children etc.

Table 6.4 Association of life course socio-economic position with health in four birth cohorts across the life course

	Brazil (Pelotas 1993)	Guatemala (INCAP)	Philippines (CLHNS)	South Africa (Birth to Twenty plus)
Body Mass Index (kg/m^2)				
Maternal schooling	-0.04 (-0.11, 0.03)	0.04 (-0.21, 0.28)	0.04 (-0.06, 0.15)	0.04 (-0.06, 0.15)
Wealth in childhood	-0.02 (-0.26, 0.21)	-1.16 (-2.46, 0.13)	0.97 (0.38, 1.57)	0.14 (-0.18, 0.46)
Relative wealth mobility in school-age	0.20 (-0.13, 0.53)	-0.2 (-1.3, 0.9)	0.67 (0.16, 1.17)	0.31 (-0.10, 0.72)
Relative wealth mobility in late adolescence	-0.06 (-0.47, 0.34)	-0.05 (-1.4, 1.3)	0.39 (-0.29, 1.07)	0.20 (-0.21, 0.61)
Relative wealth mobility in early adulthood		0.93 (-0.12, 1.98)	0.66 (0.26, 1.07)	
Attained schooling	0.03 (-0.07, 0.14)	-0.04 (-0.16, 0.08)	-0.03 (-0.12, 0.07)	0.13 (-0.03, 0.29)
Formally employed	0.20 (-0.18, 0.58)	-0.35 (-1.3, 0.6)	0.41 (-0.09, 0.90)	
Intelligence z-scores				
Maternal schooling	0.05 (0.04, 0.06)	0.05 (0.01, 0.1)	0.02 (0.00, 0.04)	0.02 (0.00, 0.04)
Wealth in childhood	0.22 (0.19, 0.26)	-0.04 (-0.27, 0.19)	0.22 (0.12, 0.33)	0.09 (0.03, 0.15)
Relative wealth mobility in school-age	0.24 (0.19, 0.29)	0.40 (0.18, 0.61)	0.18 (0.09, 0.26)	0.14 (0.06, 0.22)
Relative wealth mobility in late adolescence	0.13 (0.07, 0.19)	0.19 (-0.02, 0.41)	0.11 (0, 0.23)	0.08 (0.01, 0.16)
Relative wealth mobility in early adulthood		0.22 (-0.02, 0.46)	0.11 (0.04, 0.18)	0.11 (0.03, 0.19)
Attained schooling		0.11 (0.09, 0.14)	0.12 (0.1, 0.14)	0.2 (0.16, 0.23)
Formally employed		0.09	0.19	0.26

		(-0.1, 0.27)	(0.1, 0.29)	(0.16, 0.36)
Psychological distress z-scores				
Maternal schooling	0.01 (0, 0.02)		0.01 (-0.02, 0.03)	-0.01 (-0.03, 0.01)
Wealth in childhood	-0.06 (-0.1, -0.01)		0.09 (-0.03, 0.2)	0.04 (-0.03, 0.11)
Relative wealth mobility in school-age	-0.08 (-0.15, -0.02)		0.03 (-0.07, 0.14)	0 (-0.09, 0.08)
Relative wealth mobility in late adolescence	-0.14 (-0.21, -0.06)		0.05 (-0.07, 0.17)	0 (-0.08, 0.09)
Relative wealth mobility in early adulthood			-0.11 (-0.19, -0.02)	-0.11 (-0.19, -0.03)
Attained schooling	-0.04 (-0.06, -0.02)		0.01 (-0.02, 0.03)	-0.05 (-0.08, -0.01)
Formally employed	-0.11 (-0.18, -0.04)		0.09 (-0.03, 0.20)	0.01 (-0.10, 0.12)
Wellbeing z-scores				
Maternal schooling	0 (-0.01, 0.01)		0 (-0.02, 0.03)	0.03 (0, 0.05)
Wealth in childhood	0.06 (0.01, 0.11)		0.07 (-0.05, 0.18)	-0.08 (-0.14, -0.01)
Relative wealth mobility in school-age	0.10 (0.03, 0.17)		0.01 (-0.08, 0.1)	0.06 (-0.03, 0.15)
Relative wealth mobility in late adolescence	0.22 (0.14, 0.3)		0.06 (-0.07, 0.19)	0.04 (-0.05, 0.12)
Relative wealth mobility in early adulthood			0.21 (0.13, 0.29)	0.08 (0, 0.17)
Attained schooling	0.07 (0.04, 0.09)		0.01 (-0.01, 0.03)	0.02 (-0.02, 0.06)
Formally employed	0.18 (0.11, 0.25)		0.11 (0.01, 0.21)	0.08 (-0.03, 0.19)

Values reported are regression coefficients and 95% robust confidence intervals after adjusting for early life and adult characteristics. Sample size varies by outcome and life stage of measurement (ref **Table 6.1**). Outcomes were standardized to z-scores for Intelligence (Brazil: 12.7 units, Guatemala: 6.3 units, Philippines: 11.3 units, South Africa: 9.8 units), psychological distress (Brazil: 3.7 units, Philippines: 3.2 units, South Africa: 4.6 units), wellbeing (Brazil: 10.1 units, Philippines: 0.6 units, South Africa: 1.0 units). Wealth and conditional wealth (i.e., relative wealth mobility) were calculated from temporally harmonized asset indices created separately by cohort and are interpretable within each cohort in the same unit.

Supplementary Note 6.1 Development of conditional asset index scores

The temporally-harmonized asset index was constructed separately for each cohort by pooling data from all study waves during which a consistent set of assets (television, radio, car, etc.) and housing characteristics (such as number of rooms per resident and quality of floor) were collected. We used polychoric principal component analysis (PCA), extracted the first component and standardized it to unit variance. Using such an index allows us to compare wealth in the same dimension over time within.

Creating conditional wealth measures requires complete data on all individuals in the analytic sample. The four cohorts experienced wave-specific missingness such that non-participation in a wave did not preclude participation in a later wave. Our dataset prior to imputation consists of all individuals who provided data on any outcome variable in emerging adulthood. We excluded individuals who provided wealth data but did not provide any outcome data. We did not include the outcome variables in the multiple imputation although it might yield regression coefficients that are attenuated towards zero. We therefore created a version of conditional wealth for each imputed dataset.

1. We used multiple imputation (10 datasets; predictive mean matching) to fill in missing values for all covariates. We did not include outcome variables in the imputation.
2. For each imputed dataset, we created conditional wealth variables, which are the residuals from the below linear regression models of wealth at each life stage on previous measures of wealth. We define a one unit change in conditional wealth as the gain or loss in wealth beyond what was predicted for the sample as a whole.
   For school-age: $Wealth_{6to17} \sim Wealth_{0to5}$
   For late adolescence: $Wealth_{18to26} \sim Wealth_{0to5} + Wealth_{6to17}$
   For early adulthood: $Wealth_{27to36} \sim Wealth_{0to5} + Wealth_{6to17} + Wealth_{18to26}$
   i.e.

$$\text{Conditional Wealth}_{iT} = \text{Wealth}_{iT} - \widehat{\text{Wealth}}_{iT}$$
$$= \text{Wealth}_{iT} - [\beta_0 + \sum_{t=1}^{t=T-1} \beta_t \text{ Wealth}_{it}]$$

Year(s) of data collection used for wealth	Brazil (Pelotas 1993)	Guatemala (INCAP)	Philippines (CLHNS)	South Africa (Birth to Twenty plus)
0 to 5y	1997	1975	1983	1990
6 to 17y	2004, 2008	1987	1991, 1994, 1998	1997, 2002, 2006
18 to 26y	2011, 2015	1996	2002, 2005, 2009	2012
27 to 35y		2002	2018	2018

3. We used the conditional wealth measures generated from the respective imputed dataset in the outcome regression models. We estimated the coefficients and standard errors for

association of conditional wealth with health outcomes using combining rules for multiple imputed datasets.

Year(s) of data collection used for health	**Brazil (Pelotas 1993)**	**Guatemala (INCAP)**	**Philippines (CLHNS)**	**South Africa (Birth to Twenty plus)**
BMI	LAd: 2015 EA: -	LAd: 1998-99 EA: 2002-04	LAd: 2005, 2009 EA: 2017-18	LAd: 2012-13 EA: -
IQ	LAd: 2011 EA: -	LAd: - EA: 2002-04	LAd: - EA: 2017-18	LAd: - EA: 2017-18
Psychological distress	LAd: 2015 EA: -	LAd: - EA: -	LAd: 2005, 2009 EA: 2017-18	LAd: - EA: 2017-18
Wellbeing	LAd: 2015 EA: -	LAd: - EA: -	LAd: - EA: 2017-18	LAd: - EA: 2017-18

The conditional wealth for a participant is the change in asset index since the previous wave, beyond what was expected based on the group experience and the individual's own trajectory up to the start of the interval. This methodology has previously been used to study associations of physical growth at different life stages with adult health. A higher proportion of variance as conditional wealth of variance in cross-sectional wealth indicates high relative wealth mobility since previous measures of wealth were unable to explain the wealth distribution.

Supplementary Note 6.2 Approaches for sensitivity analysis

SA1. Sensitivity analysis for non-response due to non-participation and death

1. We estimate inverse probability weights for being alive at the time of outcome assessment using logistic regression where X are the set of early life predictors.
$$ipw_{alive} = 1/Pr[Alive = 1] = 1/(1+ e^{-\beta X})$$
2. We estimate the inverse probability weight for participating in adulthood among those who were alive using logistic regression where Z are the set of predictors for response.
$$ipw_{participated} = 1/Pr[Participated\ in\ adulthood = 1|Alive = 1] = 1/(1+ e^{-\gamma Z})$$
3. We estimate the inverse probability weight for reporting the outcome data among those who participated using logistic regression where Z are the set of predictors for response.
$$ipw_{responded} = 1/Pr[Reported\ outcome = 1|Participated = 1] = 1/(1+ e^{-\delta W})$$
4. We weight the outcome regression model with the product of the weights
$$ipw_{alive} * ipw_{participated} * ipw_{responded}$$

Our covariate set (X, Z, W) consisted of early life covariates measured at time of study enrollment, as well as suitable adult covariates among those who participated in adulthood.

Supplementary Note 6.3 Literature review for previous evidence on life course SEP and health in LMICs

Search term:

((((("2000/01/01"[Date - Publication] : "3000"[Date - Publication])) AND (life course[Title/Abstract] OR life-course[Title/Abstract])) AND (socio-economic position[Title/Abstract] OR socio-economic status[Title/Abstract] OR wealth[Title/Abstract] OR education[Title/Abstract] OR employment[Title/Abstract])) AND (body mass index[Title/Abstract] OR mental health[Title/Abstract] OR psychological distress[Title/Abstract] OR happiness[Title/Abstract] OR wellbeing[Title/Abstract] OR cognition[Title/Abstract] OR intelligence[Title/Abstract])) AND (low-income[Title/Abstract] OR LMIC[Title/Abstract] OR middle-income[Title/Abstract] OR lower middle-income[Title/Abstract])

Study	**Title**	**Status**
Davidson 2015 Nature	A focus on adolescence to reduce neurological, mental health and substance-use disability	Excluded: Provides a framework using Disability Adjusted Life Years on the importance of adolescence as a life stage
Liu 2017 Demogr. Res.	The mental health of youth and young adults during the transition to adulthood in Egypt	**Included:** Uses Self-Reporting Questionnaire-20 and empirically demonstrates the role of relationship status and unemployment on psychological distress in Egypt
Ogunsina 2018 J Glob Health	Association between life-course socio-economic status and prevalence of cardio-metabolic risk ractors in five middle-income countries	Excluded: Cross-sectional study; uses participant recall for maternal schooling and does not provide information on other domains of SEP. Strength of the study is that it explores multiple health outcomes – BMI, self-reported diabetes and hypertension from China, Mexico, India, South Africa and Russia.

Schickendanz 2015 Pediatr Clin North Am.	Childhood Poverty: Understanding and Preventing the Adverse Impacts of a Most-Prevalent Risk to Pediatric Health and Well-Being	Excluded: Provides a framework for child poverty prevention and the role of childhood adversity on life course health, education and productivity outcomes.
Varghese 2021 SSMPH	Socioeconomic position over the life-course and subjective social status in relation to nutritional status and mental health among Guatemalan adults	Excluded: Uses the INCAP Longitudinal study; reports data from middle adulthood (37-55y) for subjective social status as a primary exposure.
Varghese 2021 SSMPH	Relative and absolute wealth mobility since birth in relation to health and human capital in middle adulthood: An analysis of a Guatemalan birth cohort.	**Included:** Uses the INCAP Longitudinal study; reports data from middle adulthood (37-55y) and not early or emerging adulthood.
Selvamani 2021 BMC Geriatr	Association of life course socioeconomic status and adult height with cognitive functioning of older adults in India and China	**Included:** Uses the WHO'S Study on Global AGEing and adult health (SAGE) to examine the association of life course SES and adult height with cognition in India and China. Parental SES was retrospectively assessed. Outcomes were cross-sectionally reported in middle adults (50+y).
Hagaman 2019 PLoS One	Psychosocial determinants of sustained maternal functional impairment: Longitudinal findings from a pregnancy-birth cohort study in rural Pakistan	Excluded: Explores maternal functional trajectories following childbirth in Pakistan.
Marks 2008 Res Aging	Psychosocial Moderators the Effects of Transitioning Into Filial Caregiving on Mental and Physical Health	Excluded: Explores the role of caregiving on children's mental and physical health in United States as part of National Survey of Families and Households 1987 to 1994.

Wright 2013 Int J Nurs Stud	Impact of a nurse-directed, coordinated school health program to enhance physical activity behaviors and reduce body mass index among minority children: a parallel-group, randomized control trial	Excluded: Cluster-randomized trial for a school health program in USA
Browne-Yung 2013 Soc Sci Med	'Faking til you make it': social capital accumulation of individuals on low incomes living in contrasting socio-economic neighbourhoods and its implications for health and wellbeing	Excluded: Explored social network creation associated with social inequalities in Australia
Jeong 2021 J Adolesc Health	Determinants and Consequences of Adolescent Fatherhood: A Longitudinal Study in Ethiopia, India, Peru, and Vietnam	**Included:** Using longitudinal data from the Young Lives cohorts in Ethiopia, India, Peru and Viet Nam, this study explores the predictors and consequences of adolescent fatherhood.
Nandi 2016 BMC Public Health	The effect of an affordable daycare program on health and economic well-being in Rajasthan, India: protocol for a cluster-randomized impact evaluation study	Excluded: Evaluation of a cluster-randomized trial for affordable daycare in Rajasthan, India on mother's and child's nutritional status.
Crookston 2014 BMC Pediatr	Factors associated with cognitive achievement in late childhood and adolescence: the Young Lives cohort study of children in Ethiopia, India, Peru, and Vietnam	**Included:** Using longitudinal data from the Young Lives cohorts in Ethiopia, India, Peru and Viet Nam, this study explores the early life predictors of cognition.

Supplementary Note 6.4 Studies on association of socio-economic position and health comparing different LMICs

We reviewed empirical studies comparing the association of different domains of SEP with health in LMICs.

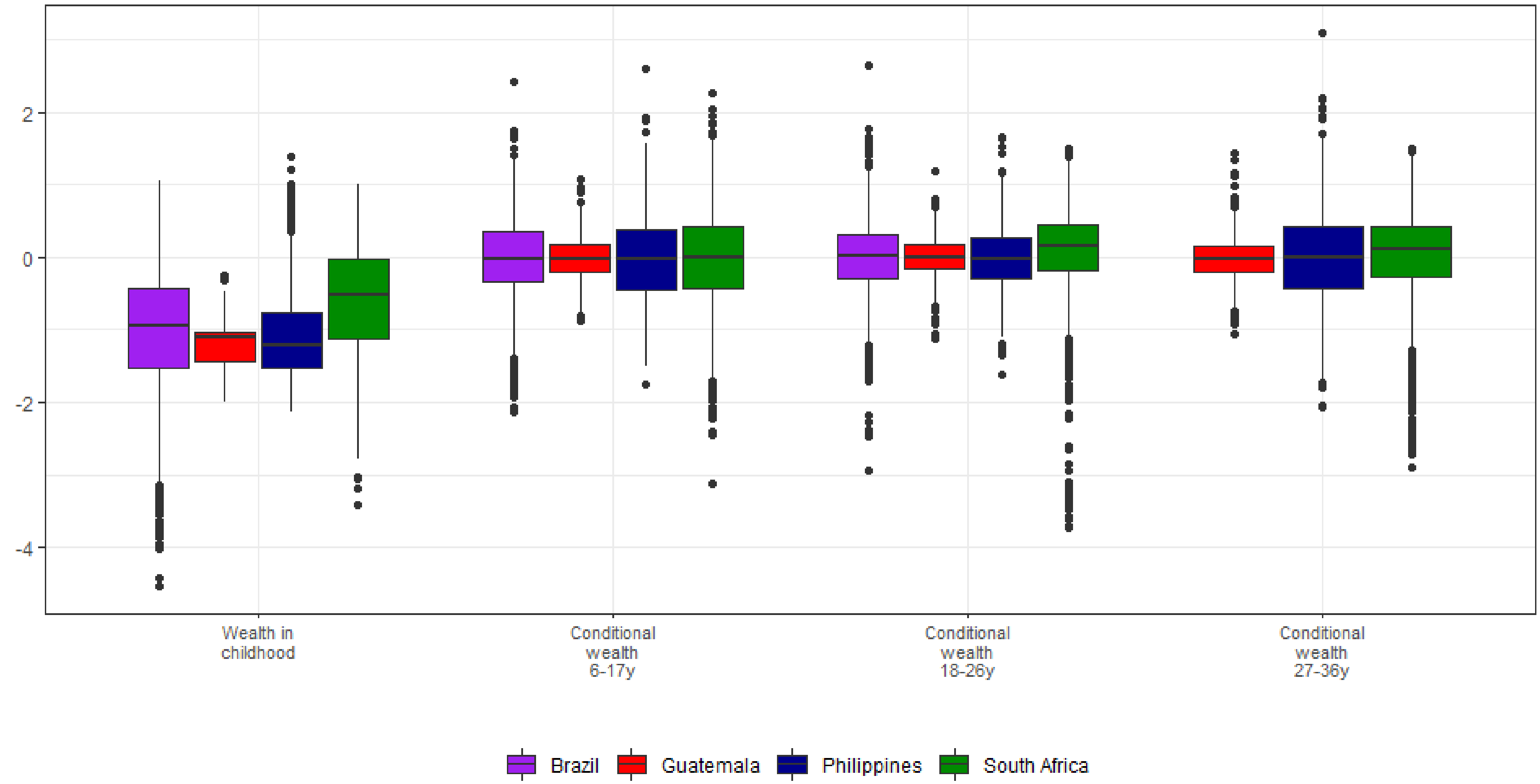
Study	Data	Title	Summary
Cardiovascular disease, obesity, diabetes			
Levy 2020 Lancet Global Health	China Kadoorie Biobank in 2004-08	Socioeconomic differences in health-care use and outcomes for stroke and ischaemic heart disease in China during 2009–16: a prospective cohort study of 0·5 million adults	Individuals in lower socio-economic position had lower hospitalization rates, but higher case fatality rates from stroke and ischemic heart disease. Lower SEP category also showed greater increases in rate of hospital admission.
Matos 2020 International Journal of Obesity	Demographic and Health Surveys 2010 to 2016 from 49 LMICs	Socioeconomic inequalities in the prevalence of underweight, overweight, and obesity among women aged 20-49 in low- and middle-income countries	Overweight or obesity increased with wealth in 44 out of 49 countries. In low-prevalence countries, increase in overweight/obesity were driven by higher prevalence among richest.
Templin 2019 PLoS Medicine	Demographic and Health Surveys 1995 to 2016 from 103 countries	The overweight and obesity transition from the wealthy to the poor in low- and middle-income countries: A survey of household data from 103 countries	Overweight prevalence is projected to increase the most among the poorest in low- and middle-income countries, while remaining unchanged in the wealthiest.
Rosengren 2019 Lancet Global Health	PURE study from 20 LIC, MIC and HIC countries	Socioeconomic status and risk of cardiovascular disease in 20 low-income, middle-income, and high-income countries: the Prospective Urban Rural Epidemiologic (PURE) study	Lower level of education was associated with higher mortality from major cardiovascular disease (deaths, strokes, myocardial infarction and heart failure), despite having better risk

			factor profile. This was attributed to poorer access to effective healthcare. Household wealth was not associated with cardiovascular disease.
McEniry 2019 Journals of Gerontology B Psychol Sci Soc Sci	Cross-sectional studies (SAGE, HRS, ELSA) from Colombia, Mexico, South Africa, USA and England	Patterns of SES Health Disparities Among Older Adults in Three Upper Middle- and Two High-Income Countries	Higher rates of depression among low SEP (as measured by education) in all countries (except South Africa - similar) versus high SEP. Lower cognition and self-reported health among low SEP in all countries. Higher hypertension, diabetes and obesity among high SEP in South Africa, while it was higher among low SEP in other countries.
Niessen 2018 Lancet	Systematic review of 279 quantitative and 4 qualitative studies from LMICs	The Lancet Taskforce on NCDs and economics 2: Tackling socioeconomic inequalities and non-communicable diseases in low-income and middle-income countries under the Sustainable Development agenda	Most studies (202 out of 279) were cross-sectional. Cohort studies (n = 21) and a case-control study suggested higher mortality from CVD for individuals in low SEP. Positive associations between poverty and NCDs (or their risk factors) was found in 73 out of 194 studies that sampled data from a general population.
Kim 2018 Lancet Global Health	Demographic and Health Surveys 2005-16 from 58 countries	Contribution of socioeconomic factors to the variation in body-mass index in 58 low-income and middle-income countries: an econometric analysis of multilevel data	Most variation of BMI was explained by between-individual differences (80%) and remaining by between-population (14% for countries, 6% for communities) differences. Socio-economic factors explained only 2% (0.1 to 6.4% from country-specific

			models) of between-individual variance in the pooled analysis.
Allen 2017 Lancet Global Health	75 studies from 39 low income and lower middle income countries	Socioeconomic status and non-communicable disease behavioural risk factors in low-income and lower-middle-income countries: a systematic review	Lower socio-economic position was associated with higher substance use (alcohol, smoking), lower consumption of fruit, vegetables, fish and fiber. Higher SEP was associated with higher processed food intake and lower physical activity. Most studies (70 out of 75) were cross-sectional and 35 were from India.
NCD Risk Factor Collaboration 2016 Lancet	Pooled analysis of 1698 studies	Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants	Mean body mass index is increasing worldwide. However, underweight remains prevalent in South Asia (India, Bangladesh, Pakistan), South-east Asia (Vietnam, Philippines) and Africa (Nigeria, Ethiopia).
Mental health, socio-emotional wellbeing			
Patel 2018 World Psychiatry	Systematic review (26 studies) and meta analysis (12 studies)	Income inequality and depression: a systematic review and meta-analysis of the association and a scoping review of mechanisms	8 out 26 studies from from LIC or MIC. Most studies (20 out of 26) were cross-sectional. Income inequality was positively associated with depression in two-thirds of all studies and five out of 6 longitudinal studies.
Lund 2018 Lancet Psychiatry	Systematic review of 289	Social determinants of mental disorders and the Sustainable Development Goals: a systematic review of reviews	Poverty is associated with higher prevalence of anxiety and depression

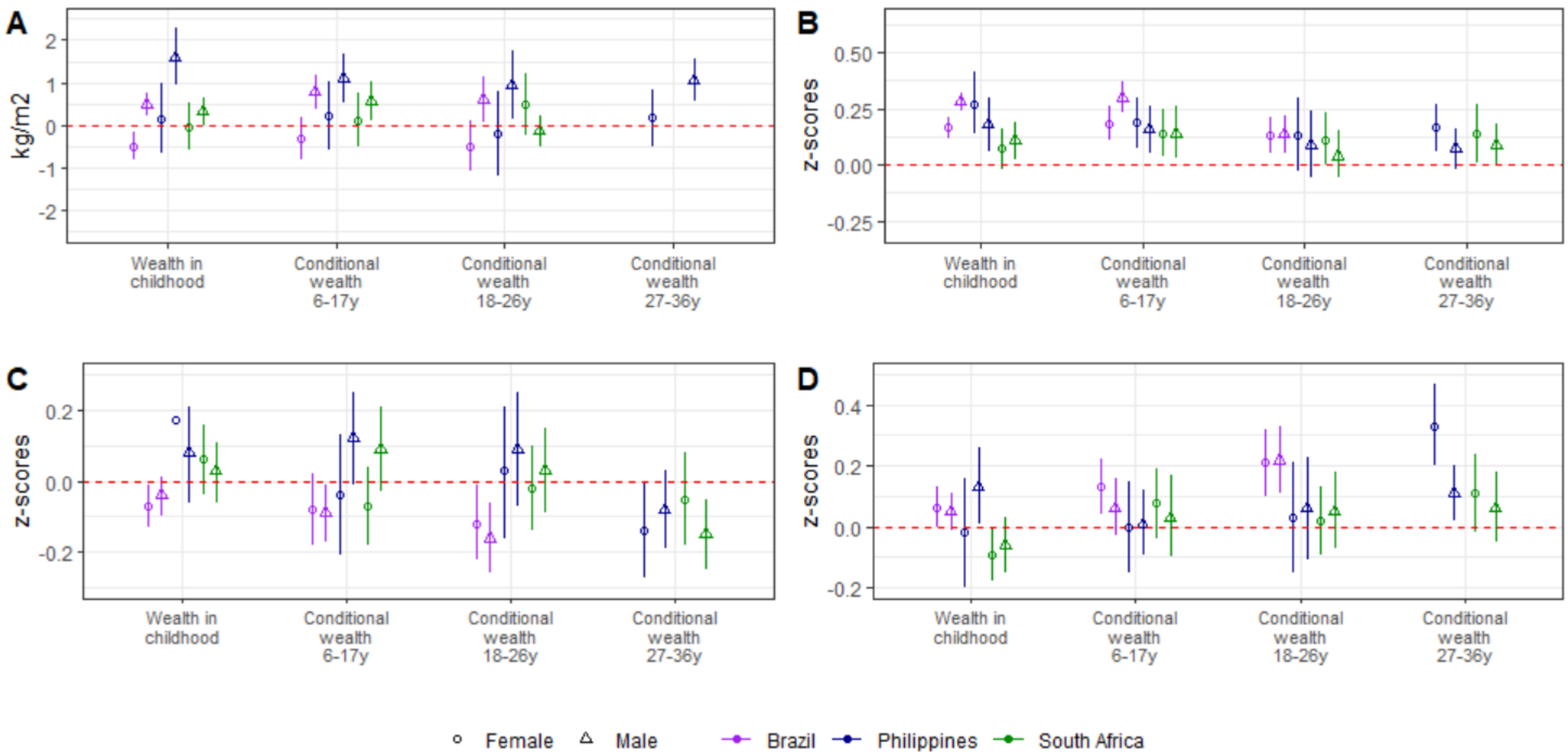
	studies from LIC, MIC, HIC		in low-income, middle-income and high-income countries.
Barry 2013 BMC Public Health		A systematic review of the effectiveness of mental health promotion interventions for young people in low and middle income countries	

Supplementary Figure 6.1 Distribution of conditional asset index at different ages for four birth cohorts



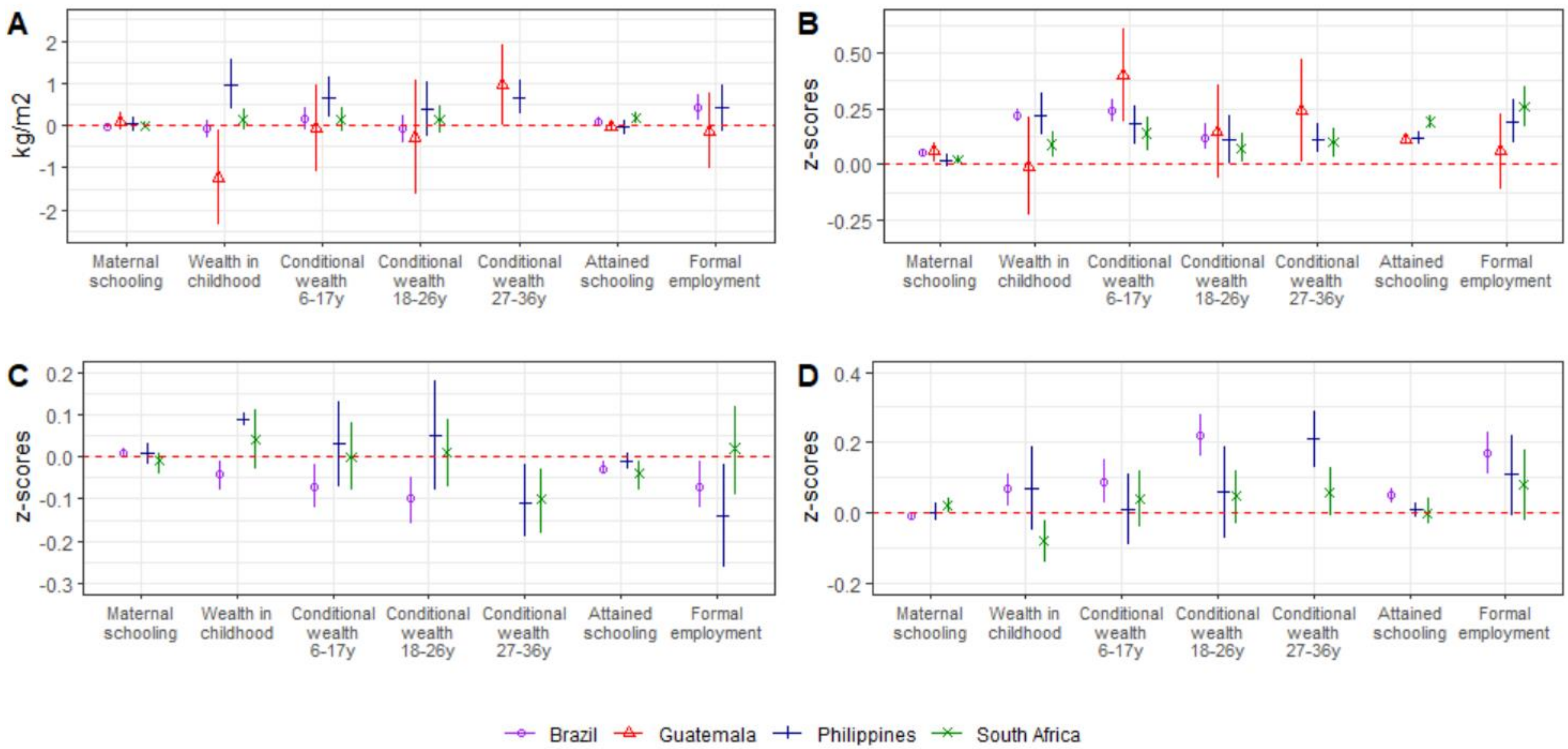
Temporally harmonized asset indices were standardized to unit variance at time of construction. Conditional wealth scores would have mean of zero and variance depending on distribution of residuals conditional on previous measures of wealth. Displayed values are conditional wealth scores averaged across imputed datasets for each individual and does not consider variance between imputed datasets. Detailed summary statistics for conditional wealth is available in **Table 6.2**.

Supplementary Figure 6.2 Association of life course socio-economic position with health and human capital in adulthood (18-36y) among males and females



A: BMI in kg/m^2, B: Intelligence in z-scores, C: Psychological distress (Perceived Stress Scale, SRQ-20) in z-scores, D: Wellbeing in z-scores; regressions were adjusted for early life covariates (maternal schooling, maternal age, birth order, sex), rural residence, attained schooling, formal employment and whether they have children.

Supplementary Figure 6.3 Association of life course socio-economic position with health and human capital in adulthood (18-36y) after adjusting for non-response or death



A: BMI in kg/m^2, B: Intelligence in z-scores, C: Psychological distress (Perceived Stress Scale, SRQ-20) in z-scores, D: Wellbeing in z-scores; regressions were adjusted for early life covariates (maternal schooling, maternal age, birth order, sex), rural residence, attained schooling, formal employment and whether they have children.

Supplementary Table 6.1 Comparison of participants in adulthood with those who did not participate due to non-response or because they died for Pelotas 1993 cohort

	Died	**Did not respond**	**Participated in adulthood**
N	171	717	4360
Maternal schooling	5.0 (3.0,8.0)	6.0 (4.0,10.0)	6.0 (4.0,9.0)
Maternal age	26.4±7.1	25.6±6.4	26.0±6.4
Mother employed at enrollment	91.8%	92.3%	93.9%
Maternal skin color (= white)	68.4%	82.4%	76.9%
Birth order	3.0 (1.0,4.0)	2.0 (1.0,3.0)	2.0 (1.0,3.0)
Male sex	52.6%	56.1%	48.4%

Supplementary Table 6.2 Comparison of participants in adulthood with those who did not participate due to non-response or because they died for INCAP cohort 1971-75

	Died	**Did not respond**	**Participated in adulthood**
N	141	224	560
Maternal schooling	1.0 (0.0,2.0)	1.0 (0.0,2.0)	1.0 (0.0,2.0)
Maternal age	27.5±8.2	26.4±7.1	26.8±7.1
Birth order	4.0 (2.0,4.0)	3.0 (2.0,4.0)	4.0 (2.0,4.0)
Male sex	61.0%	59.8%	47.5%
Atole supplementation	54.6%	54.0%	51.4%
Wealth in childhood	-1.1 (-1.4,-1.0)	-1.1 (-1.3,-1.0)	-1.1 (-1.4,-1.0)

Supplementary Table 6.3 Comparison of participants in adulthood with those who did not participate due to non-response or because they died for Cebu Longitudinal Health and Nutrition Study 1983-84

	Died	**Did not respond**	**Participated in adulthood**
N	61	1692	1327
Maternal schooling	6.0 (4.0,8.0)	6.0 (5.0,10.0)	6.0 (5.0,9.0)
Maternal age	25.0±6.5	26.1±5.9	26.6±6.2
Birth order	3.0 (1.0,4.0)	3.0 (2.0,4.0)	3.0 (2.0,4.0)
Male sex	77.0%	51.4%	53.9%
Wealth in childhood	-0.3 (-0.8,0.3)	-0.2 (-0.7,0.6)	-0.3 (-0.8,0.4)
Rural residence in childhood	31.1%	19.6%	28.0%

Supplementary Table 6.4 Comparison of participants in adulthood with those who did not participate due to non-response or because they died for Birth to Twenty plus cohort 1990

	Did not respond or Died	Participated in adulthood
N	1876	1397
Maternal schooling	9.0 (9.0,11.5)	9.0 (9.0,11.5)
Maternal age	26.1±5.9	25.8±6.3
Birth order	2.0 (1.0,3.0)	2.0 (1.0,3.0)
Male sex	49.5%	47.5%
Skin color (= black)	71.1%	88.4%

Supplementary Table 6.5 Characteristics in early life and adulthood of female participants in four birth cohorts, among those who reported any outcome in adulthood (18-36y)

	Brazil (Pelotas 1993)[a] n = 2249		Guatemala (INCAP)[b] n = 294		Philippines (CLHNS)[c] n = 612		South Africa (Birth to Twenty plus)[d] n = 877	
	N	**Summary**	**N**	**Summary**	**N**	**Summary**	**N**	**Summary**
Early life covariates								
Maternal schooling	2246	6.0 [4.0,9.0]	291	0.0 [0.0,2.0]	612	6.0 [5.0,8.0]	817	9.0 [9.0,11.5]
Maternal age	2249	26.1±6.3	293	27.0±7.3	612	26.5±6.1	875	25.6±6.2
Maternal skin color (= white)	2247	76.2%						
Birth order	2249		291		612		877	
Male sex	2249	0%	294	0%	612	0%	877	0%
Atole supplementation			294	51.4%				
Exposure to supplementation in first 1000 days			294	86.4%				
Skin color (= white)	2130	60.2%						
Skin color (= black)							877	88.8%
Adult covariates [e]								
Formal employment	2025	25.6%	293	16.0%	612	30.6%	858	39.6%
Attained schooling	2025	11 [9, 12]	293	5 [2, 6]	612	11 [11, 13]	858	12 [11, 12]
Married	2025	44.2%	285	78.9%	611	51.7%	720	13.1%
Currently pregnant[f]		55		18		26		0
Have children	2023		286	97.3%	611	85.8%	737	54.4%
Rural residence			294	68.7%	611	32.8%		
Life course wealth								
Wealth in childhood	602	-1.0±1.1	294	-1.2±0.3	612	-1.1±0.6	791	-0.6±0.9
Wealth during school age (6-17y)	2182	-0.2±0.9	239	-0.7±0.4	612	-0.1±0.8	811	<0.1±0.8

Wealth in emerging adulthood (18-26y)	2246	0.4±0.7	133	-0.2±0.5	611	0.3±0.7	818	0.5±0.8
Wealth in early adulthood (18-26y)			170	0.1±0.5	611	0.9±0.8	734	0.6±0.7
Health outcomes								
Body Mass Index (kg/m^2)	1874	25.5±5.7	247	26.5±4.5	582	25.2±5.0	764	25.5±6.2
Wechsler Adult Intelligence Scale –IV (WAIS-IV)	2070	97.0 [88.0,105.0]						
Ravens Progressive Matrices			287	16.0 [13.0,19.5]	612	32.0 [23.0,41.0]	734	38.0 [31.0,44.0]
SRQ-20	2017	4 [2,7]			611	3 [1, 5]	734	7 [3, 11]
Warwick-Edinburgh Mental Well-being Scale (WEMWS)	1885	51.0 [44.0,57.0]						
Lyubomirsky Subjective Happiness Scale					611	3.8 [3.2, 4.0]	734	4.0 [3.0, 5.0]

Supplementary Table 6.6 Characteristics in early life and adulthood of male participants in four birth cohorts, among those who reported any outcome in adulthood (18-36y)

	Brazil (Pelotas 1993)[a] n = 2111		Guatemala (INCAP)[b] n = 266		Philippines (CLHNS)[c] n = 715		South Africa (Birth to Twenty plus)[d] n = 823	
	N	**Summary**	**N**	**Summary**	**N**	**Summary**	**N**	**Summary**
Early life covariates								
Maternal schooling	2107	6.0 [4.0,9.0]	264	1.0 [0.0,2.0]	715	6.0 [5.0,9.0]	760	9.0 [9.0,11.5]
Maternal age	2110	26.0±6.5	263	26.5±6.9	715	26.6±6.2	823	26.0±6.3
Maternal skin color (= white)	2111	77.5%						
Birth order	2111	2 [1, 3]	263	4 [2, 4]	715	3 [2, 4]	823	2 [1, 3]
Male sex	2111	100%	266	100%	715	100%	823	100%
Atole supplementation			266	51.5%				
Exposure to supplementation in first 1000 days			266	86.8%				
Skin color (= white)	1953	64.1%						
Skin color (= black)							823	87.8%
Adult covariates [e]								
Formal employment	1777	34.4%	208	55.6%	715	38.7%	647	30.4%
Attained schooling	1772	11 [8, 11]	259	6 [3, 6]	715	11 [9, 13]	810	11 [10. 12]
Married	1777	34.5%	239	78.2%	715	42.2%	639	8.3%
Currently pregnant[f]		-		-		-		-
Have children	1772	19.9%	237	100%	715	80.1%	663	38.9%
Rural residence			266	79.7%	715	34.1%		
Life course wealth								
Wealth in childhood	535	-1.0±1.2	266	-1.2±0.3	715	-1.1±0.6	736	-0.6±0.9
Wealth during school age (6-17y)	2023	-0.2±0.9	229	-0.7±0.4	715	-0.1±0.8	757	<0.1±0.7

Wealth in emerging adulthood (18-26y)	2109	0.5±0.6	135	-0.2±0.5	715	0.3±0.7	762	0.5±0.8
Wealth in early adulthood (18-26y)			189	0.1±0.5	715	0.9±0.9	660	0.5±0.9
Health outcomes								
Body Mass Index (kg/m^2)	1687	25.0±4.8	233	24.3±3.4	711	24.8±4.4	742	21.6±3.7
Wechsler Adult Intelligence Scale –IV (WAIS-IV)	1767	97.0 [87.0,105.0]						
Ravens Progressive Matrices			257	19 [15, 25]	715	33 [24, 41]	662	39 [33, 44]
SRQ-20	1630	2 [1, 5]			715	1 [0 3]	662	5 [2, 8]
Warwick-Edinburgh Mental Well-being Scale (WEMWS)	1630	55 [48, 59]						
Lyubomirsky Subjective Happiness Scale					715	3.5 [3.0, 3.8]	663	4.0 [3.0, 5.0]

Supplementary Table 6.7 Sex stratified association of life course socio-economic position with health in adulthood

	Brazil (Pelotas 1993)		Philippines (CLHNS)		South Africa (Birth to Twenty plus)	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
Body Mass Index (kg/m²)						
Wealth in childhood	-0.49 (-0.8, -0.17)	0.49 (0.23, 0.75)	0.16 (-0.64, 0.97)	1.61 (0.95, 2.27)	-0.04 (-0.59, 0.52)	0.33 (-0.01, 0.66)
Conditional wealth in school-age	-0.31 (-0.79, 0.17)	0.78 (0.37, 1.19)	0.23 (-0.57, 1.04)	1.10 (0.52, 1.67)	0.13 (-0.51, 0.77)	0.58 (0.13, 1.03)
Conditional wealth in emerging adulthood	-0.48 (-1.06, 0.1)	0.6 (0.07, 1.14)	-0.19 (-1.18, 0.8)	0.95 (0.16, 1.75)	0.48 (-0.24, 1.2)	-0.12 (-0.48, 0.24)
Conditional wealth in early adulthood			0.17 (-0.50, 0.83)	1.07 (0.58, 1.56)		
Intelligence z-scores						
Wealth in childhood	0.17 (0.12, 0.21)	0.28 (0.24, 0.32)	0.27 (0.14, 0.41)	0.18 (0.06, 0.3)	0.07 (-0.02, 0.16)	0.11 (0.02, 0.19)
Conditional wealth in school-age	0.18 (0.11, 0.26)	0.3 (0.23, 0.37)	0.19 (0.07, 0.3)	0.16 (0.05, 0.26)	0.14 (0.04, 0.25)	0.14 (0.03, 0.26)
Conditional wealth in emerging adulthood	0.13 (0.05, 0.21)	0.14 (0.05, 0.22)	0.13 (-0.03, 0.3)	0.09 (-0.06, 0.24)	0.11 (0, 0.23)	0.04 (-0.06, 0.15)
Conditional wealth in early adulthood			0.17 (0.06, 0.27)	0.07 (-0.02, 0.16)	0.14 (0.01, 0.27)	0.09 (-0.01, 0.18)
Psychological distress z-scores						
Wealth in childhood	-0.07 (-0.13, -0.01)	-0.04 (-0.1, 0.01)	0.17 (-0.01, 0.34)	0.08 (-0.06, 0.21)	0.06 (-0.04, 0.16)	0.03 (-0.06, 0.11)
Conditional wealth in school-age	-0.08 (-0.18, 0.02)	-0.09 (-0.17, -0.01)	-0.04 (-0.21, 0.13)	0.12 (-0.01, 0.25)	-0.07 (-0.18, 0.04)	0.09 (-0.03, 0.21)
Conditional wealth in emerging adulthood	-0.12 (-0.22, -0.01)	-0.16 (-0.26, -0.06)	0.03 (-0.16, 0.21)	0.09 (-0.07, 0.25)	-0.02 (-0.14, 0.1)	0.03 (-0.09, 0.15)

Conditional wealth in early adulthood			-0.14 (-0.27, 0)	-0.08 (-0.19, 0.03)	-0.05 (-0.18, 0.08)	-0.15 (-0.25, -0.05)
Wellbeing z-scores						
Wealth in childhood	0.06 (0, 0.13)	0.05 (-0.01, 0.11)	-0.02 (-0.2, 0.16)	0.13 (0.01, 0.26)	-0.09 (-0.18, 0)	-0.06 (-0.15, 0.03)
Conditional wealth in school-age	0.13 (0.04, 0.22)	0.06 (-0.03, 0.16)	0 (-0.15, 0.15)	0.01 (-0.09, 0.12)	0.08 (-0.04, 0.19)	0.03 (-0.1, 0.17)
Conditional wealth in emerging adulthood	0.21 (0.1, 0.32)	0.22 (0.11, 0.33)	0.03 (-0.15, 0.21)	0.06 (-0.11, 0.23)	0.02 (-0.09, 0.13)	0.05 (-0.07, 0.18)
Conditional wealth in early adulthood			0.33 (0.2, 0.47)	0.11 (0.02, 0.2)	0.11 (-0.02, 0.24)	0.06 (-0.05, 0.18)

Sample size varies by outcome and life stage of measurement (ref **Supplementary Table 6.5 to 6.6**)

Supplementary Table 6.8 Association with health outcomes after adjusting for non-participation

	Brazil (Pelotas 1993)	Guatemala (INCAP)	Philippines (CLHNS)	South Africa (Birth to Twenty plus)
Body Mass Index (kg/m²)				
Maternal schooling	-0.02 (-0.07, 0.03)	0.09 (-0.12, 0.3)	0.04 (-0.06, 0.15)	0 (-0.08, 0.08)
Wealth in childhood	-0.07 (-0.28, 0.13)	-1.23 (-2.36, -0.11)	0.97 (0.4, 1.55)	0.14 (-0.1, 0.39)
Conditional wealth in school-age	0.16 (-0.11, 0.44)	-0.06 (-1.08, 0.95)	0.67 (0.18, 1.15)	0.13 (-0.16, 0.43)
Conditional wealth in emerging adulthood	-0.08 (-0.4, 0.24)	-0.28 (-1.63, 1.06)	0.39 (-0.25, 1.03)	0.14 (-0.17, 0.46)
Conditional wealth in early adulthood		0.95 (0.02, 1.89)	0.66 (0.27, 1.06)	
Attained schooling	0.1 (0.02, 0.19)	-0.03 (-0.15, 0.08)	-0.03 (-0.13, 0.07)	0.18 (0.06, 0.3)
Formally employed	0.43 (0.13, 0.74)	-0.13 (-1.01, 0.75)	0.41 (-0.15, 0.96)	
Intelligence z-scores				
Maternal schooling	0.05 (0.04, 0.06)	0.06 (0.01, 0.1)	0.02 (0, 0.04)	0.02 (0, 0.04)
Wealth in childhood	0.22 (0.19, 0.25)	-0.01 (-0.23, 0.21)	0.22 (0.13, 0.32)	0.09 (0.03, 0.15)
Conditional wealth in school-age	0.24 (0.19, 0.29)	0.4 (0.19, 0.61)	0.18 (0.09, 0.26)	0.14 (0.06, 0.21)
Conditional wealth in emerging adulthood	0.12 (0.07, 0.18)	0.15 (-0.06, 0.36)	0.11 (0, 0.22)	0.07 (0.01, 0.14)
Conditional wealth in early adulthood		0.24 (0.01, 0.47)	0.11 (0.05, 0.18)	0.1 (0.03, 0.16)
Attained schooling		0.11 (0.09, 0.14)	0.12 (0.1, 0.14)	0.19 (0.16, 0.22)
Formally employed		0.06	0.19	0.26

		(-0.11, 0.23)	(0.1, 0.29)	(0.17, 0.35)
Psychological distress z-scores				
Maternal schooling	0.01 (0, 0.02)		0.01 (-0.02, 0.03)	-0.01 (-0.04, 0.01)
Wealth in childhood	-0.04 (-0.08, -0.01)		0.09 (-0.03, 0.21)	0.04 (-0.03, 0.11)
Conditional wealth in school-age	-0.07 (-0.12, -0.02)		0.03 (-0.07, 0.13)	0 (-0.08, 0.08)
Conditional wealth in emerging adulthood	-0.1 (-0.16, -0.05)		0.05 (-0.08, 0.18)	0.01 (-0.07, 0.09)
Conditional wealth in early adulthood			-0.11 (-0.19, -0.02)	-0.1 (-0.18, -0.03)
Attained schooling	-0.03 (-0.04, -0.01)		-0.01 (-0.03, 0.01)	-0.04 (-0.08, -0.01)
Formally employed	-0.07 (-0.12, -0.01)		-0.14 (-0.26, -0.02)	0.02 (-0.09, 0.12)
Wellbeing z-scores				
Maternal schooling	-0.01 (-0.02, 0)		0 (-0.02, 0.03)	0.02 (0, 0.04)
Wealth in childhood	0.07 (0.02, 0.11)		0.07 (-0.05, 0.19)	-0.08 (-0.14, -0.02)
Conditional wealth in school-age	0.09 (0.03, 0.15)		0.01 (-0.09, 0.11)	0.04 (-0.04, 0.12)
Conditional wealth in emerging adulthood	0.22 (0.16, 0.28)		0.06 (-0.07, 0.19)	0.05 (-0.03, 0.12)
Conditional wealth in early adulthood			0.21 (0.13, 0.29)	0.06 (-0.01, 0.13)
Attained schooling	0.05 (0.03, 0.07)		0.01 (-0.01, 0.03)	0 (-0.03, 0.04)
Formally employed	0.17 (0.11, 0.23)		0.11 (-0.01, 0.22)	0.08 (-0.02, 0.18)

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Chapter 7 Subjective social status is associated with happiness but not weight status or psychological distress: an analysis of three prospective birth cohorts from low- and middle-income countries

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Short running head: Subjective social status and health in LMIC cohorts

Abbreviations: BMI: Body Mass Index; PCA: Principal Component Analysis; PCR: Perceived Community Respect ladder; PES: Perceived Economic Status ladder; SEP: Socio-economic Position; SHS: Subjective Happiness Scale; SRQ-20: World Health Organization Self-Reporting Questionnaire-20; SSS: Subjective Social Status;

Data availability statement: The code for the analysis is available on https://github.com/jvargh7/cohorts-subjective-status. Data will be available upon reasonable request addressed to the principal investigators at each study site.

ABSTRACT

Background:

Subjective social status (SSS, perception of social position relative to a frame of reference) has been associated with physical, mental and socio-emotional wellbeing. However, these associations may be susceptible to unmeasured confounding by life course objective socio-economic position (such as wealth, education and employment) and life satisfaction. Our objective is to estimate the association of position on ladders of perceived community respect and perceived economic status with different health outcomes, independent of objective SEP in cohorts from three low and middle-income countries.

Methods:

We used data from birth cohorts in Guatemala (n = 1258), Philippines (n = 1323) and South Africa (n = 1393). We estimated the association of perceived community respect and perceived economic status with body mass index (kg/m^2), the World Health Organization's Self-Reported Questionnaire-20 (SRQ-20) for psychological distress, and Lyubomirsky's Subjective Happiness Scale. We estimated these associations using robust linear regression models adjusting for indicators of life course objective SEP, early life characteristics, adult covariates, and life satisfaction. We explored heterogeneity in associations by sex, schooling and wealth.

Results:

Participants in South Africa (age 27-28y) rated themselves higher on average for both the respect (7 vs 5 in Guatemala and 6 in Philippines) and economic (5 vs 3 in Guatemala and 4 in

Philippines) ladder measures. Position on neither community respect nor economic ladders were associated with BMI or psychological distress. Higher position on community respect (Guatemala: 0.03, 95%CI: 0.01, 0.04; Philippines: 0.03, 95% CI: 0.02, 0.05; South Africa: 0.07, 95%CI: 0.04, 0.09) and economic (Guatemala: 0.02, 95%CI: 0, 0.04; Philippines: 0.04, 95%CI: 0.02, 0.07; South Africa: 0.07, 95%CI: 0.04, 0.10) ladders were similarly associated with greater happiness, and associations were consistent across levels of schooling or wealth in all cohorts. Evidence suggestive of heterogeneity by sex was observed for association of economic ladder with BMI in Guatemala and Philippines and for SRQ-20 and happiness in Guatemala.

Conclusions:

Subjective social status showed small but consistent associations with happiness in birth cohorts independent of life-course SEP.

KEYWORDS: Subjective social status, perceived community respect, perceived economic status, socioeconomic status, BMI, happiness, psychological distress, early life factors, gender

Introduction

Subjective social status (SSS) is one's own evaluation socio-economic position (SEP) over the life course, relative to others in one's community, on measures such as perceived respect and perceived economic status (1). SEP is a function of material (e.g. wealth), human (e.g. schooling) and social (e.g. networks) capital (2). Higher SSS has been found to be associated with lower rates of depression, cardiovascular disease and all-cause mortality, independent of objective SEP measures such as wealth, education and employment status (3-6). Given the self-reported nature of SSS and its associations with health measures such as self-rated health and psychological distress, some criticisms included correlated measurement error and confounding by temporary mood. However, experimental studies of allocation into upward or downward comparison standards for SSS showed that such associations are robust to confounding by temporary mood (7, 8).

We present a conceptual framework of how SSS is associated with health in **Figure 7.1**. SEP over the life course is associated with life satisfaction (evaluative wellbeing) (9, 10). SSS is considered to be a 'cognitive average' of objective SEP relative to others in their community (3). SSS may also be influenced by personality traits and factors such as locus of control and life satisfaction (11). Previous research exploring mediation of the association of SSS and health-related stress responses by general life stressors showed null findings and suggested that alternate mediating pathways directly related to social status related stressors (such as financial stress and dominance) are understudied (12). SSS may operate through relative deprivation and stress-related biological pathways (such as the hypothalamus-pituitary-adrenal axis and sympathetic nervous system) (11). Relative deprivation, driven by inequality and lower relative position (disadvantage within a community relative to others), is associated with lack of control over circumstances and opportunities for social participation (13, 14). Such deprivation is different from absolute poverty (lack of resources) that confers additional disadvantages.

Observational studies from high-income settings suggest that associations of SSS and health vary by outcome, race, sex and country (15-17). The scarce evidence on heterogeneous associations from cross-sectional surveys in low- and middle-income countries is consistent with available evidence from high-income settings (18, 19). However, research on SSS may be susceptible to epidemiological biases further reducing generalizability – specifically correlated measurement error from self-reported instruments and unmeasured confounders such as life course objective SEP, life satisfaction and personality traits (e.g. self-esteem) (11). Unbiased estimates for association of SSS with health is important to design appropriate interventions.

Using birth cohorts from three LMICs, we explore our a priori hypothesis (derived from our conceptual framework in **Figure 7.1**) that subjective social status was associated with health beyond life course wealth, own and parental schooling and life satisfaction. Consistent associations across different LMIC settings in cohorts born across a range of birth years, with varying environmental exposures, and confounding structures would suggest generalizable results (20). Our objective is to study the association of SSS on multiple dimensions of health, i.e. physical, mental and socio-emotional well-being, among study populations in three countries, independent of objective SEP (21).

2 Methods

2.1 Study Population

We use life-course data from three birth cohorts that are part of the Consortium of Health Oriented Research in Transitioning Societies (COHORTS) collaborative (22). The cohorts are from countries in three different continents: Guatemala (INCAP Longitudinal Study), Philippines (Cebu Longitudinal Health and Nutrition Survey, born in 1983-84) and South Africa (Birth to Twenty plus Cohort, born in 1990) (23-25). The Guatemala cohort was followed from birth only for those born in the period 1969 to 1977. We obtained ethical approval for this secondary analysis from Emory University IRB (Protocol 95960).

2.2 Data collection and variable specification

2.2.1 Subjective Social Status

Subjective Social Status was measured using the MacArthur Ladder in adulthood (2017-18; Guatemala: 37-55y, Philippines: 35-36y, South Africa: 27-28y) (3). Participants were asked to visualize a ladder that represents their community. They were asked the following questions to assess (a) Perceived Community Respect (‘respect ladder’), and (b) Perceived Economic Status (‘economic ladder’) respectively.

a) On a scale of 1 to 10, where 10 are the people who have the most respectable position and the most respectable jobs in the community and 1 are the people with the least respectable or no work jobs. Where would you place yourself?

b) On a scale of 1 to 10, where 10 are the people who have more money and greater wealth and 1 are the people who have the least money and the least wealth, where would you place yourself?

Though the ladder measures were not validated in these specific contexts, they have been used in LMIC settings (19).

2.2.2 Life course objective socio-economic position

Life course measures of objective SEP, namely wealth, schooling and employment, were available for all cohorts (22). We developed cross-sectional asset indices from contextually relevant set of assets (such as television, car etc) and housing characteristics (house ownership, housing material etc). The asset indices were estimated separately for each cohort as measures of relative wealth in childhood (Guatemala: 1967 or 1975, Philippines: 1983-84, South Africa: 1990-92) and adulthood (Guatemala: 2015-18, Philippines: 2017-18, South Africa: 2017-18) (26). We used the first component from a polychoric principal component analysis (PCA) of asset data and standardized it to unit variance. Schooling measures, collected at the most recent wave and at enrollment, for participants and their mothers, respectively, reflect final school attainment. Employment status in adulthood was classified into formal or informal/unemployed/not seeking work.

2.2.3 Health and wellbeing

We investigated three health and wellbeing outcomes: body mass index as a measure of physical health, psychological distress as a measure of mental health and happiness as a measure of socio-emotional wellbeing (21).

Height and weight were measured in 2015-16 for Guatemala and in 2017-18 for Philippines using standardized protocols. We computed body mass index (BMI; kg/m^2) as weight (kg) divided by square of height (m). Height and weight were not collected for the South African cohort at the time SSS data were collected. There was high prevalence of overweight or obese (BMI $\geq$ 25 kg/m^2) in Guatemala (females: 78.2%, males: 62.9%) and Philippines (females: 47.5%, males: 44.9%), with low prevalence of underweight (BMI < 18.5 kg/m^2; Guatemala: 9.8%, Philippines: 5.5%).

Psychological distress was measured using the WHO Self-Reported Questionnaire (SRQ-20), a 20-item instrument (per item; yes: 1, no: 0) which is widely used in low-resource settings as a screening tool for mental distress (27). We summed the counts of psychological distress symptoms (range: 0 to 20). Subjective happiness was measured using the 4-item (per item; low: 1, high: 5) Lyubomirsky Subjective Happiness Scale (SHS) (28). We averaged the responses of SHS items to a range of 1 to 5. Both SRQ-20 and SHS were administered in 2017-18 for Guatemala and Philippines. For South Africa, SRQ-20 and one item from the SHS scale were asked in 2017-18.

2.2.4 Early life and adult covariates

We adjusted for a common set of early life covariates (maternal age, maternal schooling, birth order and sex of participant) across all cohorts. Additionally, we adjusted for cohort-specific covariates (Guatemala: year and village of birth; Philippines: rural residence, South Africa: whether skin color was Black). We included adult covariates measured concurrently with the outcomes: adult life satisfaction (measured using NIH Toolbox Item Bank v2.0 – General Life Satisfaction), whether participants have children (yes/no), marital status (married/co-habiting versus not) and residence in adulthood (for Guatemala and Philippines, rural vs. urban) (29). The South Africa cohort is comprised entirely of urban residents.

2.3 Statistical Analysis

We carried out our analysis separately by cohort. The analytic sample was restricted to those participants who provided information on both measures of subjective social status and at least one health outcome in adulthood (n; Guatemala: 1258, Philippines: 1323, South Africa: 1393). A flowchart for selection of the analytic sample is available in **Supplementary Fig 7.1**. Since there were missing values for some covariates and health outcomes, we used multiple imputation (10 datasets, 50 iterations, predictive mean matching) under missing at random assumptions. We included subjective social status (respect and economic ladders), life course objective SEP, auxiliary variables (early life covariates, adult covariates) and outcome variables (BMI, SRQ-20, SHS) in the imputation model. Outcome variables included in the imputation stage with auxiliary variables may provide more precise effect estimates and better coverage probability of 95% confidence intervals, without any other loss of performance (30, 31). We did not delete imputed outcomes from the analysis datasets.

We used linear regression with robust standard errors to estimate the association between each component of the SSS and our outcome variables separately even when normality and homoskedasticity assumptions of the residuals were violated. We accounted for clustering by maternal identifier in Guatemala and current barangay (neighborhood) of residence in Philippines using marginal models. We fit models without any covariates (Model 1) and sequentially adjusted (including all preceding variables) for SEP and life satisfaction (Model 2), early life and adult covariates (Model 3), and effect modification of association of SSS and health by sex (Model 4a), attained schooling (Model 4b) or wealth in adulthood (Model 4c). We excluded women who were pregnant from analysis of BMI.

2.4 Sensitivity Analysis

We performed three sensitivity analyses to assess the robustness of our findings (details in **Supplementary Note 7.1**). First, we repeated our analysis after adjusting for additional cross-sectional measures of life course wealth (in previous life stages) to estimate any residual confounding by SEP. Second, we used e-values to quantify the extent of unmeasured confounding of the SSS and health associations. The e-value for an exposure-outcome association is the minimum strength of association an unmeasured confounder should have with both the exposure (i.e. subjective social status) and outcome (BMI/SRQ-20/SHS) to nullify the observed association (32). Third, we repeated our analysis after using inverse probability of censoring weights to account for non-participation (due to death or non-response) in adulthood (33).

All analysis was carried out using R 3.6.1. The code for the analysis is available at https://github.com/jvargh7/cohorts-subjective-status.

3 Results

Descriptive characteristics of the analytic sample are provided in **Table 7.1**. Participants in South Africa (age 27-28y) rated themselves higher than those in the other two cohorts for both the respect (7 vs 5 in Guatemala and 6 in Philippines) and economic (5 vs 3 in Guatemala and 4 in Philippines) ladders.

The distribution of SSS (**Supplementary Fig 7.2 to 7.4**) did not differ by sex, residence (urban vs rural in Guatemala and Philippines), or skin color (Black vs other in South Africa). The SSS measures (**Supplementary Fig 7.5 A-C**) were positively correlated with each other, while SRQ-

20 and Subjective Happiness Scale (SHS) were negatively correlated (**Supplementary Fig 7.5 D-F)**.

3.1 Association of subjective social status with health and wellbeing

We present associations from linear regression in **Table 2**. In the model without covariate adjustment (Model 1), the respect ladder was associated with BMI in Philippines (0.15 kg/m^2 per 1-point difference, 95% CI: 0.04, 0.25), while the economic ladder was associated with BMI in Philippines (0.31, 95%CI: 0.14, 0.49) and Guatemala (0.17, 95%CI: 0.04, 0.31). After adjusting for life course SEP and life satisfaction (Model 2), neither respect ladder, nor economic ladder were associated with BMI in Philippines. The association of BMI and economic ladder attenuated (0.07 kg/m^2 per 1-point difference, 95%CI: -0.07, 0.20) on adjusting for all covariates (Model 3).

Crude inverse associations between the economic ladder and psychological distress also did not persist after adjustment for life course SEP, life satisfaction and other covariates (Model 3) in Philippines (-0.16 units SRQ-20 per 1-point difference in ladder, 95%CI: -0.43, 0.11) and South Africa (-0.05 units SRQ-20, 95%CI: -0.20, 0.09). The respect ladder was also not associated with psychological distress in any cohort.

Both the respect ladder and economic ladder were positively associated with the subjective happiness scale for all three cohorts after adjusting for life course objective SEP, early and adult covariates and life satisfaction. The associations between both ladders and subjective happiness were similar in magnitude. For example, in South Africa, one-unit difference in respect ladder was associated with 0.07 unit (95%CI: 0.04, 0.09) change in the subjective happiness scale while one-unit difference in economic ladder was associated with 0.07 unit (95%CI: 0.04, 0.10) change in subjective happiness scale.

3.2 Effect modification of association of subjective social status with health and wellbeing

We observed evidence suggestive of heterogeneity (**Supplementary Table 7.2**) by sex for the association of the economic ladder with BMI in Guatemala (male-female difference: 0.22 kg/m^2 per 1-point change, 95%CI: -0.06, 0.50) and Philippines (male-female difference: 0.52 kg/m^2, 95%CI: 0.15, 0.90). We also observed potential heterogeneity by sex in Guatemala for association of the economic ladder with happiness (male – female difference: -0.05 units per 1-point change, 95%CI: -0.09, 0.00) and psychological distress (male – female difference: 0.23 units, 95%CI: 0.07, 0.39). We did not observe any other heterogeneous associations by sex, attained schooling or adult wealth (**Supplementary Tables 7.2, 7.3 and 7.4**) for either ladder across cohorts since differences were small in magnitude.

3.3 Sensitivity analysis

The observed associations of respect and economic ladders with health outcomes did not differ after adjusting for additional life course wealth measures (**Supplementary Fig 7.4**). Similarly, the results did not change after accounting for attrition using inverse probability weights except for association of economic status with psychological distress (**Supplementary Fig 7.5**).

Our analysis for unmeasured confounding using e-values (**Table 7.3**) suggested that an unmeasured confounder stronger (under an assumption of equal scale) than cross-sectional wealth or formal employment would be required to nullify the observed association of the respect ladder and economic ladder with happiness across all sites. For example, when estimating the association of economic ladder with happiness, wealth (0.05 units per 1 unit of wealth, 95%CI: -0.01, 0.10) and formal employment (0.06 units, 95%CI: -0.03, 0.16) were positively associated with happiness in Guatemala. The e-value for the same association is 0.16 (CI: 0.01).

4 Discussion

Our results from birth cohorts in three LMICs suggest that subjective social status, as either community respect or economic status, is positively associated with happiness but is not associated with weight status (participants were predominantly overweight or obese), and psychological distress. These associations did not differ by levels of schooling or wealth, although there was some evidence of heterogeneity by sex. The results were robust to alternate model specifications, and suggested only an unmeasured confounder stronger than adult wealth and formal employment, reliable markers of SEP in LMICs, could nullify the observed association.

This research extends previous investigation of subjective social status with health outcomes in Guatemala by including two new settings and additionally considering life satisfaction, marital status, and whether they had children (34). Subjective wellbeing consists of three domains: evaluative wellbeing (life satisfaction), emotional wellbeing (experienced wellbeing) and eudaimonic wellbeing (e.g. meaning and purpose). The first is a long-term evaluation of one's life experiences, while the second is related to one's frequency of positive (positive affect; like happiness and pleasure) and negative (negative affect; like shame, fear and anger) feelings (35). Subjective social status and happiness (an indicator of positive affect) were positively associated in all three cohorts, after adjusting for markers of objective SEP, consistent with research from representative samples of adults in 29 countries, including Philippines and South Africa (19). Low SSS was previously shown to be associated with chronic negative affect, potentially as lack of power (control) and social acceptance in western societies (7, 8, 36). A randomized study among three hundred adult participants from US suggested that low subjective status was associated with negative affect (7). Although life satisfaction and emotional wellbeing may be interrelated, the demonstrated empirical association of SSS (a hypothesized life course evaluation) with emotional wellbeing, beyond life satisfaction, is suggestive of the relative deprivation hypothesis that one’s place in the society may influence their emotional state (13, 14).

Results from a meta-analysis of 38 studies (6 were from LMICs) and from 20 household surveys in 18 countries (11 were LMICs) suggest higher subjective social status was associated with better mental health (37, 38). Additionally, the observed null findings for association of cross-sectional wealth and psychological distress after adjusting for subjective social status is consistent with results from LMICs such as Myanmar and Uganda (18, 39). The null findings for subjective social status and BMI in Philippines and Guatemala were also consistent with research from East Asia and Mexico, as well as Adler et.al.’s original study among women in USA (1, 40, 41). However, other research from high-income countries (England, USA) has shown negative associations of subjective status with BMI (42, 43). These associations of SSS and BMI are susceptible to reverse causation with body image and cultural ideals, but not health, being mediators. Together with these results, our findings suggest that subjective social status may be a reliable marker for wellbeing but not weight status in non-western societies.

Previous research from a predominantly rural and food insecure population in Malawi compared the economic ladder question to cross-sectional asset indices. In this population, the ladder measure was more strongly correlated with absolute poverty, as measured by household expenditures, than the wealth index, since the latter was partly determined by community infrastructure (such as electricity) (44). Though both the ladder and the asset index measure relative deprivation in the community, the former may be more useful for programmatic targeting especially when relative wealth categories (such as quintiles) may not be easily translatable into absolute poverty. This could be the case with skewed distributions (high inequality), acute financial distress (such as famine or natural disasters) and studies in catchment areas with high rates of poverty. However, the subjective nature of the measure deems it susceptible to measurement error and therefore, a combination of many SEP measures could be used for identifying at-risk households.

4.1 Strengths and limitations

Our study has many strengths, including duration of follow-up, availability of data on early life SEP, adjustment for life course SEP and life satisfaction as well as outcome data collected using consistent methodology across three cohorts. However, there are some limitations. Firstly, our outcomes and adult SEP were measured cross-sectionally. Hence, our results that suggest SSS may predict health (social causation) is susceptible to reverse causality such that poor health may result in lower SSS (health selection). However, evidence from Europe suggests that both social causation and health selection operate in early life and adolescence, while social causation is the predominant mechanism in adulthood (45). Secondly, the measures of subjective social status, SRQ-20 and Subjective Happiness Scale were not validated in the context of these particular countries. These measures have been used previously in South Africa as well as other low- and middle-income countries (Brazil, India, Indonesia, Myanmar, Uganda, Vietnam, and Zambia) (18, 19, 39, 46-54). Third, our analytic sample consists of birth cohorts that are not representative of their respective countries. All the cohorts were community-based and we did not observe differential loss to follow-up. We also did not observe any differences in distribution of SSS by sex and region of residence. Using only a single item from the Subjective Happiness Scale for South Africa may bias our reported estimates, compared to the other cohorts. However, given the consistent associations observed between SSS and different health outcomes, we believe our results are generalizable across settings in spite of these limitations. Fourth, we did not explore the heterogeneity of association with high school completion or with different types of non-formal engagement (informal, unemployed, not seeking work) in the job market since these are important indicators of objective SEP in LMIC settings. Furthermore, we did not estimate three-way heterogeneity with schooling or wealth by sex due to low sample sizes. Finally, though our hypotheses were decided a priori, we test the association of two measures of SSS with three outcomes across many model formulations, potentially warranting an adjustment of significance level for multiple comparisons. Such an analysis was beyond the scope of this paper and hence was not included.

4.2 Conclusion

Our research demonstrates consistent associations for SSS and happiness, beyond general life satisfaction and objective SEP, across three cohorts from LMICs at different stages of economic development. Further research on the implications of low subjective status for individual health in LMIC contexts ought to be conducted given that there might be cultural differences in how subjective status manifested, and how status comparisons may be influenced by cultural or community norms as well as life course SEP (55). Research from western societies suggest comparison of one's position relative to others may induce feelings of frustration, shame, social rejection or perceived lack of control (7, 36). Interventions such as cognitive behavioral therapy, group psychotherapy, supportive psychotherapy, Langerian mindfulness or social skills training are helpful in western societies for dealing with shame, perceived lack of control and other mental illness, and may be culturally adapted for use in LMICs (4, 56-61). Interventions related to socio-economic position for improving emotional wellbeing in low- and middle-income countries should consider the role of perceived status, and not solely objective markers of SEP.

Ethics approval and consent to participate: All participants gave written informed consent before participation. Ethical approval for the latest study wave for the cohorts were obtained from the Institutional Review Board of Emory University, USA (Protocol 95960), Institute of Nutrition for Central America and Panama, Guatemala (Protocol CIE-REV-072-2017), Research Ethics Committee at University of San Carlos, Philippines (Protocol 006/2018-01-borja), and Human Research Ethics Committee at University of Witswatersrand, South Africa (Certificate No. M180225)**.**

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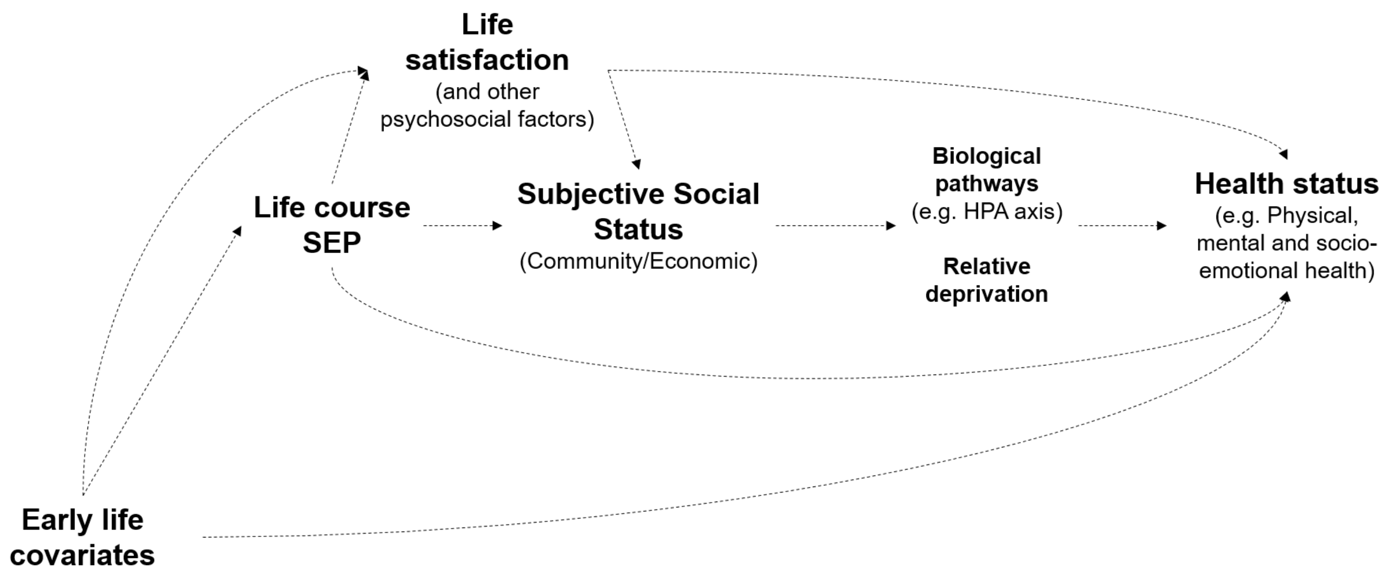
Table 7.1 Early life and adult characteristics for analytic sample

	Guatemala (INCAP) N = 1258		**Philippines (CLHNS) N = 1323**		**South Africa (Birth to Twenty plus) N = 1393**	
	N	Summary	N	Summary	N	Summary
Subjective Social Status						
Perceived Community Respect	1258	5 [3, 8]	1323	6 [5, 8]	1393	7 [5, 8]
Perceived Economic Status	1258	3 [1,5]	1323	4 [3,5]	1393	5 [4,5]
Socio-economic position						
Maternal schooling (years)	1221	1 [0,2]	1323	6 [5,9]	1290	9 [9,12]
Attained schooling (years)	1258	6 [2,6]	1323	11 [9,13]	1392	12 [11,12]
Formal employment	1251	48.8%	1323	35.0%	1365	43.6%
Early life covariates						
Maternal age (years)	1249	26 [21, 32]	1323	26 [22, 32]	1391	25 [21, 32]
Birth order	1247	4 [2, 4]	1323	3 [2, 4]	1393	2 [1, 3]
Male	1258	44.6%	1323	53.9%	1393	47.4%
Birth year	1258	1970 [1967, 1974]	1323	1983-84	1393	1990
Rural residence in childhood		-	1323	28.0%		
Black skin color		-		-	1393	88.4%
Adult covariates [a]						
Is married	1258	52.1%	1323	46.5%	1354	10.8%
Have children	1159	99.8%	1323	82.8%	1393	52.6%
Is pregnant		1		26		66
Rural residence in adulthood	1258	73.1%	1323	33.6%		-
General life satisfaction [b]	1244	19 [17, 21]	1323	18 [17, 20]	1386	17 [14, 20]
Health outcomes						
Body Mass Index (kg/m^2)	1022	28.1±5.0	1290	25.0±4.6	1393	-
Psychological distress [c]	1257	3 [1,6]	1323	2 [0,4]	1393	6 [3,10]
Subjective Happiness Scale	1244	4 [4,5]	1323	3.5 [3.2, 4.0]	1392	4 [3,5]

All values displayed as mean ± standard deviation or median [25^{th} percentile, 75^{th} percentile] for continuous variables and percentage (%) for categorical variables;

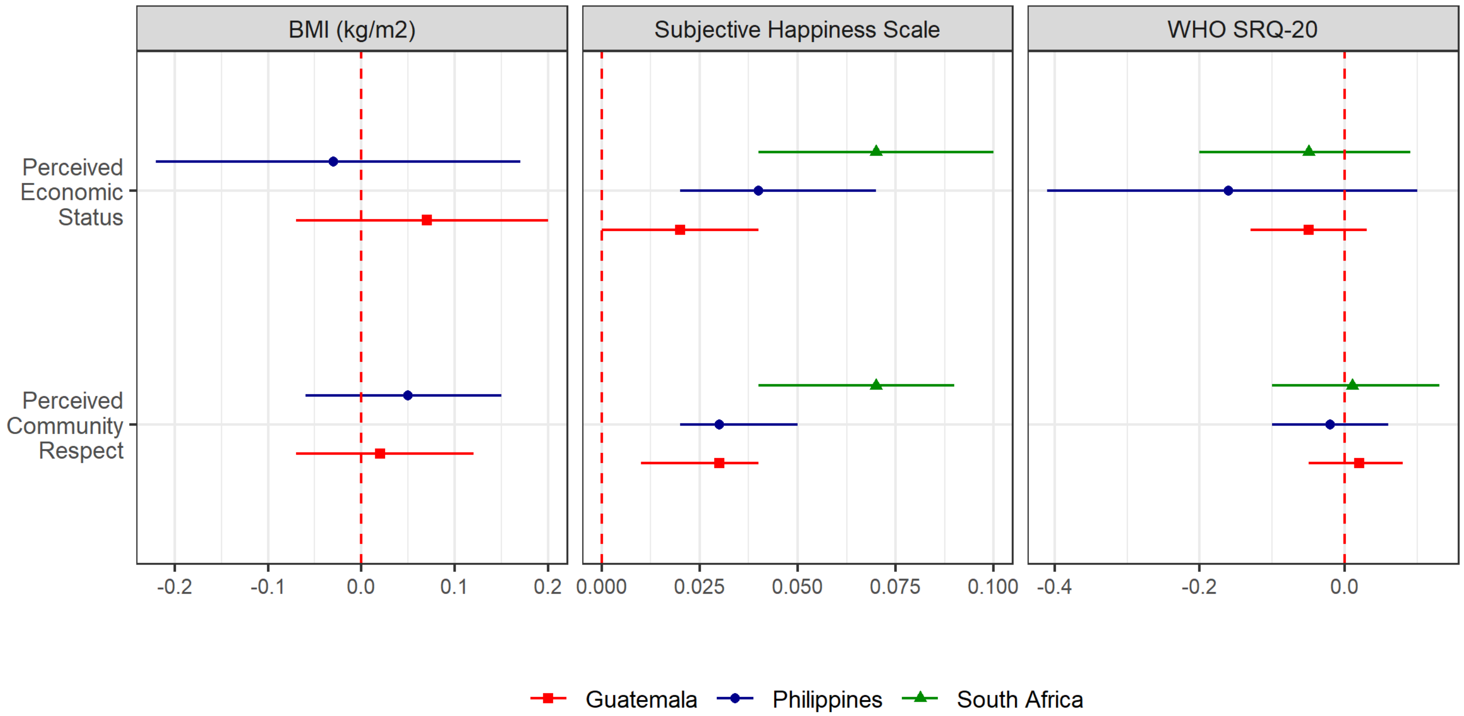
[a] Wealth in childhood and adulthood were based on cross-sectional asset indices;
[b] General life satisfaction was measured using the NIH Toolbox Item Bank v2.0
[c] WHO SRQ-20 is a 20-item psychological distress scale. Values greater than or equal to 7 may indicate mental distress.

Figure 7.1 Framework for association of subjective social status with health and wellbeing



SEP: Socio-economic position; HPA: Hypothalamus-Pituitary-Adrenal axis is a stress-related endocrine pathway. Pathways from life course SEP to biological and psychosocial pathways are not displayed. Life satisfaction and subjective social status may be determined by prior health status.

Figure 7.2 Associations of SSS with health and wellbeing outcomes with adjustment for life course SEP measures by cohort



Associations were estimated from linear regressions. Models (Model 3C, Model 3E) were fit separately for perceived community respect and perceived economic status) adjusted for socio-economic position (wealth in childhood and adulthood, maternal and attained schooling, formal employment), early life covariates and adult covariates (including life satisfaction, marital status and children – yes/no).

Table 7.2 Association of subjective social status with health and wellbeing after progressive adjustment for covariates

	Guatemala (INCAP) N = 1258			Philippines (CLHNS) N = 1323			South Africa (Birth to Twenty plus) N = 1393		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Perceived Community Respect									
Body Mass Index (kg/m^2)	0.03 (-0.07, 0.13)	0.00 (-0.1, 0.1)	0.02 (-0.07, 0.12)	0.15 (0.04, 0.25)	0.05 (-0.06, 0.15)	0.05 (-0.06, 0.15)			
SRQ-20	-0.07 (-0.15, 0)	0.00 (-0.07, 0.07)	0.02 (-0.05, 0.08)	-0.01 (-0.09, 0.07)	0.04 (-0.03, 0.12)	-0.02 (-0.1, 0.06)	-0.08 (-0.2, 0.05)	0.03 (-0.09, 0.15)	0.01 (-0.1, 0.13)
Subjective Happiness Scale	0.05 (0.03, 0.07)	0.03 (0.01, 0.04)	0.03 (0.01, 0.04)	0.06 (0.04, 0.08)	0.04 (0.03, 0.06)	0.03 (0.02, 0.05)	0.1 (0.07, 0.12)	0.07 (0.04, 0.09)	0.07 (0.04, 0.09)
Perceived Economic Status									
Body Mass Index (kg/m^2)	0.17 (0.04, 0.3)	0.10 (-0.04, 0.23)	0.07 (-0.07, 0.2)	0.31 (0.14, 0.49)	0.00 (-0.19, 0.19)	-0.03 (-0.22, 0.17)			
SRQ-20	-0.1 (-0.18, -0.02)	-0.02 (-0.11, 0.06)	-0.05 (-0.13, 0.03)	-0.12 (-0.23, 0)	-0.04 (-0.17, 0.08)	-0.16 (-0.41, 0.1)	-0.27 (-0.42, -0.13)	-0.04 (-0.18, 0.1)	-0.05 (-0.2, 0.09)
Subjective Happiness Scale	0.05 (0.03, 0.07)	0.02 (0, 0.04)	0.02 (0, 0.04)	0.1 (0.07, 0.12)	0.06 (0.04, 0.08)	0.04 (0.02, 0.07)	0.13 (0.09, 0.16)	0.07 (0.04, 0.1)	0.07 (0.04, 0.1)

All coefficients displayed are for subjective social status. Model 1: Subjective social status; Model 2: Model 1 + life course SEP (wealth, maternal and own schooling, own formal employment) + life satisfaction; Model 3: Model 2 + early life covariates + adult covariates

Table 7.3 E-values for unmeasured confounding for association of subjective social status with health and wellbeing

	Guatemala (INCAP) N = 1258			**Philippines (CLHNS) N = 1323**			**South Africa (Birth to Twenty plus) N = 1393**		
	Coefficient for Wealth in adulthood	**Coefficient for Formal employment**	**e-value**	**Coefficient for Wealth in adulthood**	**Coefficient for Formal employment**	**e-value**	**Coefficient for Wealth in adulthood**	**Coefficient for Formal employment**	**e-value**
Perceived Community Respect									
Body Mass Index (kg/m^2)	0.58 (0.17, 0.99)	-0.13 (-0.78, 0.53)	0.07; CI: 0	0.68 (0.34, 1.01)	0.4 (-0.11, 0.9)	0.11; CI: 0			
SRQ-20	-0.26 (-0.51, -0.02)	0.07 (-0.36, 0.50)	0.08; CI: 0	0.05 (-0.18, 0.28)	-0.38 (-0.83, 0.06)	0.09; CI: 0	-0.08 (-0.34, 0.19)	0.71 (0.22, 1.2)	0.05; CI: 0
Subjective Happiness Scale	0.05 (-0.01, 0.1)	0.06 (-0.03, 0.16)	0.2; CI: 0.11	0.02 (-0.02, 0.06)	0.05 (-0.01, 0.1)	0.26; CI: 0.21	0 (-0.06, 0.06)	-0.11 (-0.21, -0.01)	0.31; CI: 0.23
Perceived Economic Status									
Body Mass Index (kg/m^2)	0.55 (0.14, 0.96)	-0.12 (-0.77, 0.54)	0.13; CI: 0	0.71 (0.36, 1.06)	0.41 (-0.1, 0.92)	0.09; CI: 0			
SRQ-20	-0.23 (-0.48, 0.01)	0.07 (-0.36, 0.51)	0.13; CI: 0	0.17 (-0.14, 0.48)	-0.31 (-1, 0.38)	0.26; CI: 0	-0.07 (-0.33, 0.19)	0.73 (0.24, 1.22)	0.11; CI: 0
Subjective Happiness Scale	0.04 (-0.02, 0.1)	0.07 (-0.02, 0.17)	0.16; CI: 0.01	0.01 (-0.03, 0.05)	0.04 (-0.02, 0.1)	0.3; CI: 0.21	-0.01 (-0.07, 0.05)	-0.11 (-0.21, -0.01)	0.31; CI: 0.23

Coefficients displayed are for association of wealth in adulthood and formal employment with different health outcomes based on Model 3 (adjusted for life course socio-economic position, early life and adult life covariates, life satisfaction).

Supplementary Note 7.1 Details on Sensitivity Analyses for robustness of findings

Analysis 1. Residual confounding by life course relative wealth

Model 3:

E[Outcome] = b0 + b1 Subjective Social Status + c X + d Z

where X: Early life SEP (maternal schooling, early life relative wealth) and adult SEP at time of outcome measurement (attained schooling, formal employment, adult relative wealth)

where Z: early life and adult covariates (Section 2.4 in Manuscript)

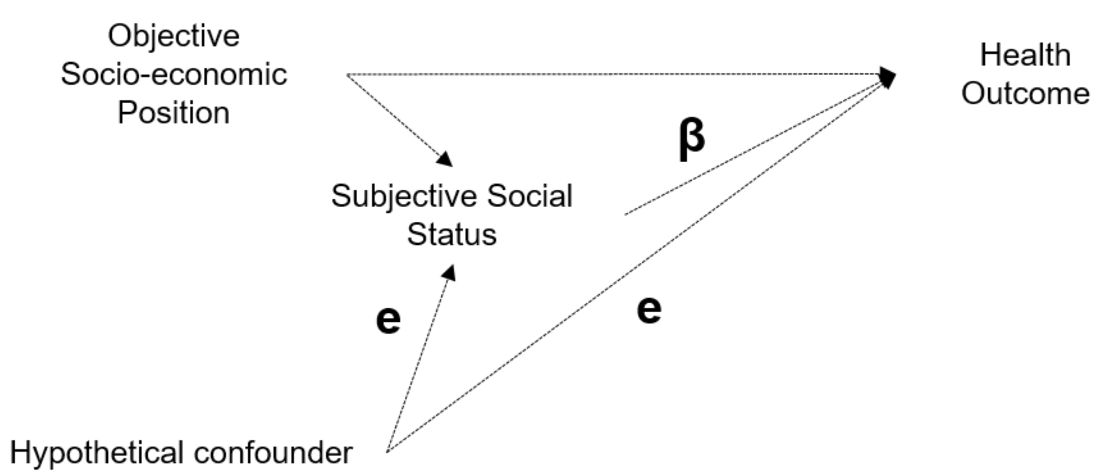
Analysis 1 Model: b0 + b1 Subjective Social Status + c X + d Z + e W

where W: relative wealth in other study waves measured prior to subjective social status ladders.

- Guatemala: in 1987, 1996, 2002
- Philippines: in 1991, 1994, 1998, 2002, 2005, 2009
- South Africa: in 1997, 2002, 2006, 2012

Analysis 2. Extent of unmeasured confounding for SSS-Outcome association

Below figure is reproduced from Varghese 2021 SSMPH (Supplementary Figure 2). "e" is the e-value for unmeasured confounding or the minimum strength of association an unmeasured confounder should have with both the exposure (subjective social status) and outcome (such as BMI, psychological distress using WHO Self-Reported Questionnaire-20 and happiness using Subjective Happiness Scale) to nullify the observed association (β).



Analysis 3. Censoring weights for non-participation due to death or non-response

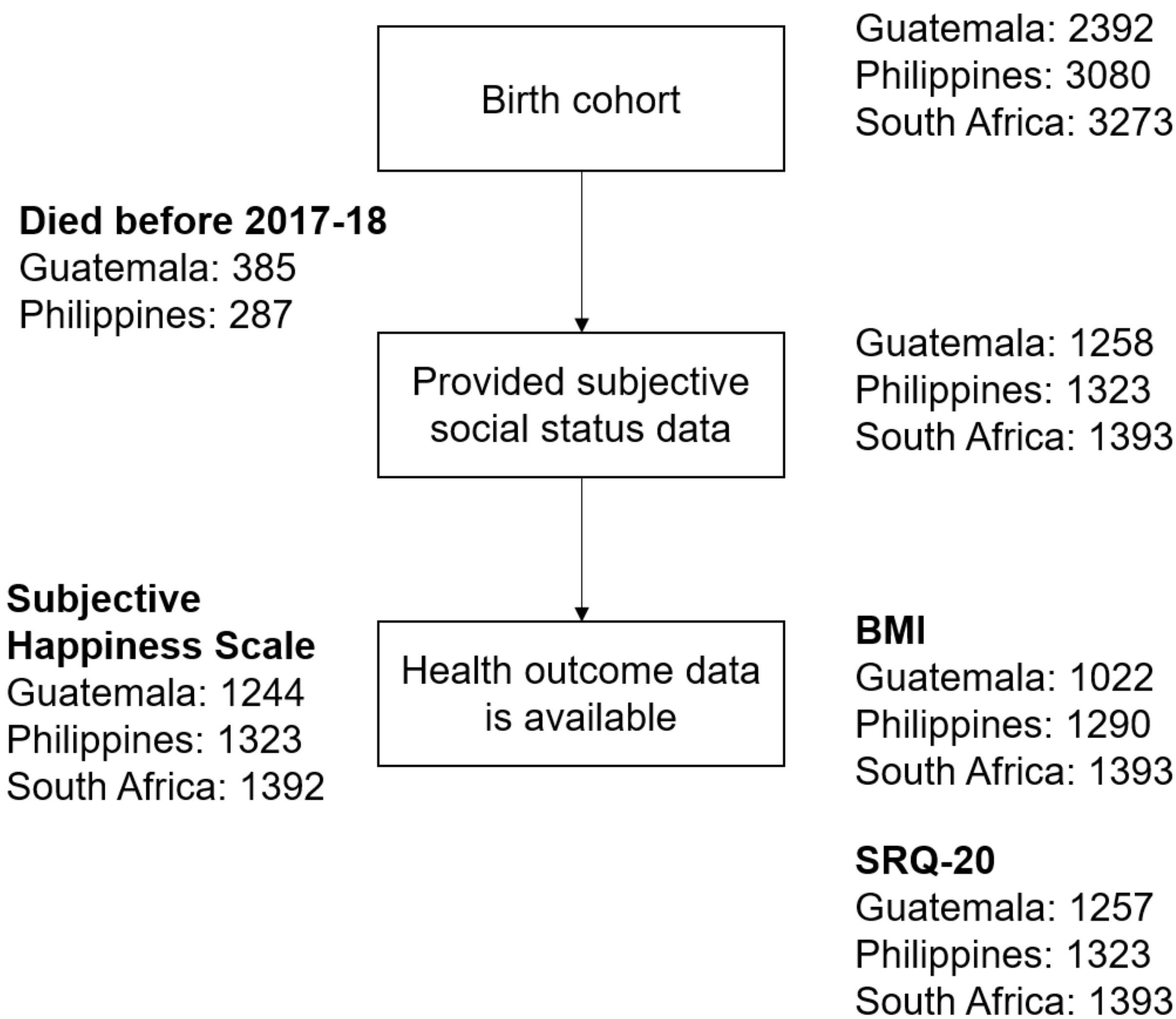
W_{death} : Weight for death: 1/Pr[Alive = 1|Early life covariates]

Wsss: Weight for providing SSS: 1/Pr[Provided SSS = 1|Early life covariates]

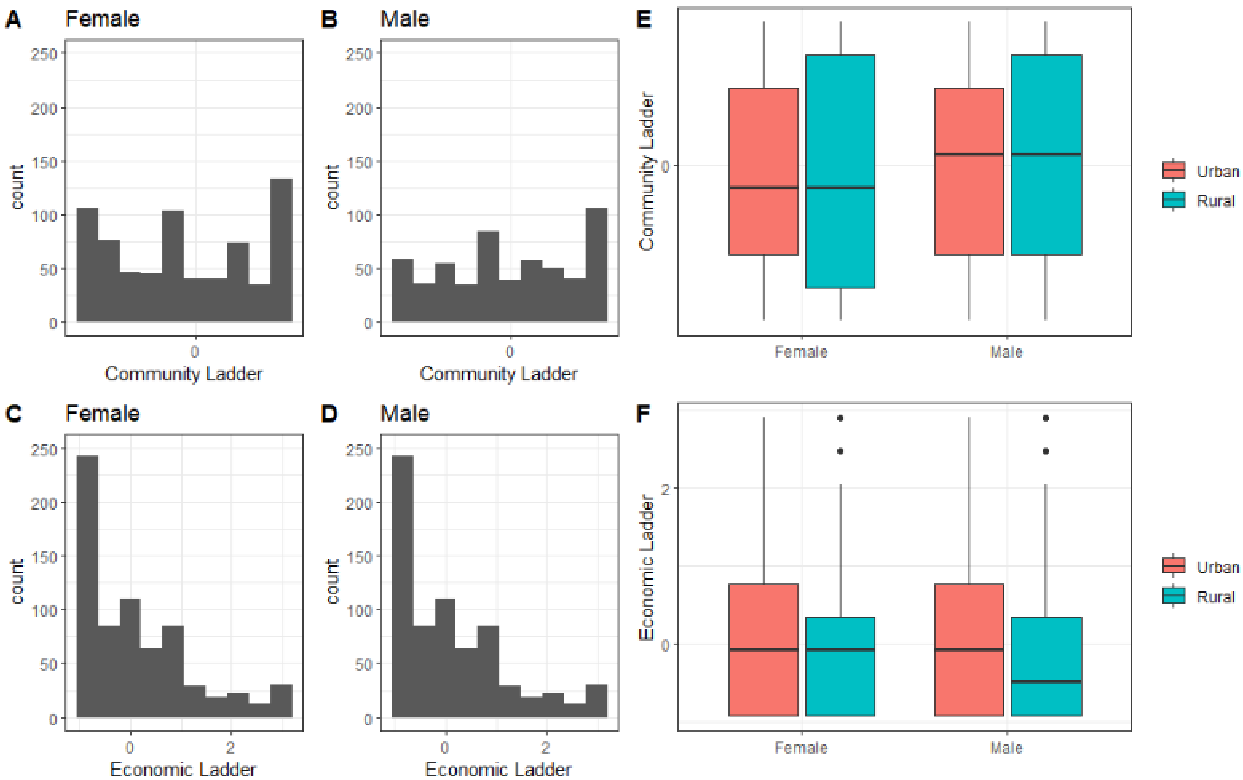
$W_{Outcome}$: Weight for providing each health outcome: 1/Pr[Provided Outcome = 1|Early life covariates, Adult covariates]

Censoring weight = W_{death} * Wsss * $W_{Outcome}$

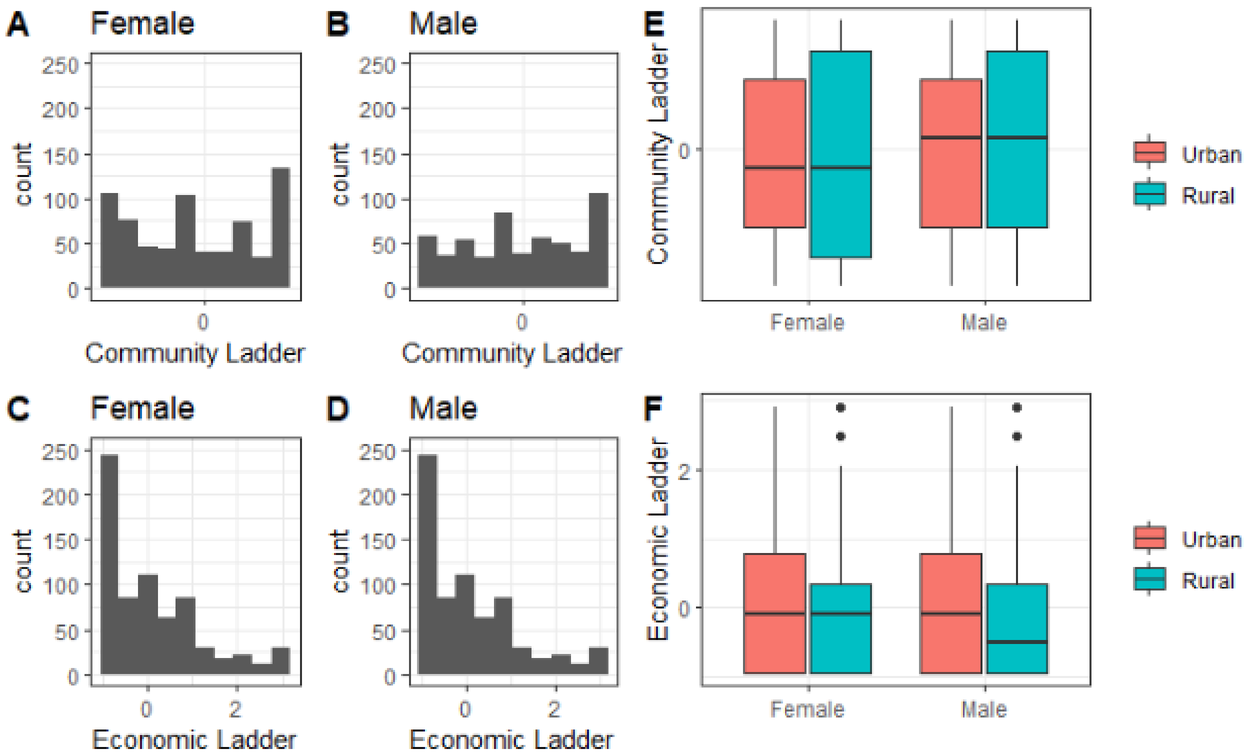
Supplementary Figure 7.1 Flowchart for analytic sample construction in three low- and middle-income country cohorts



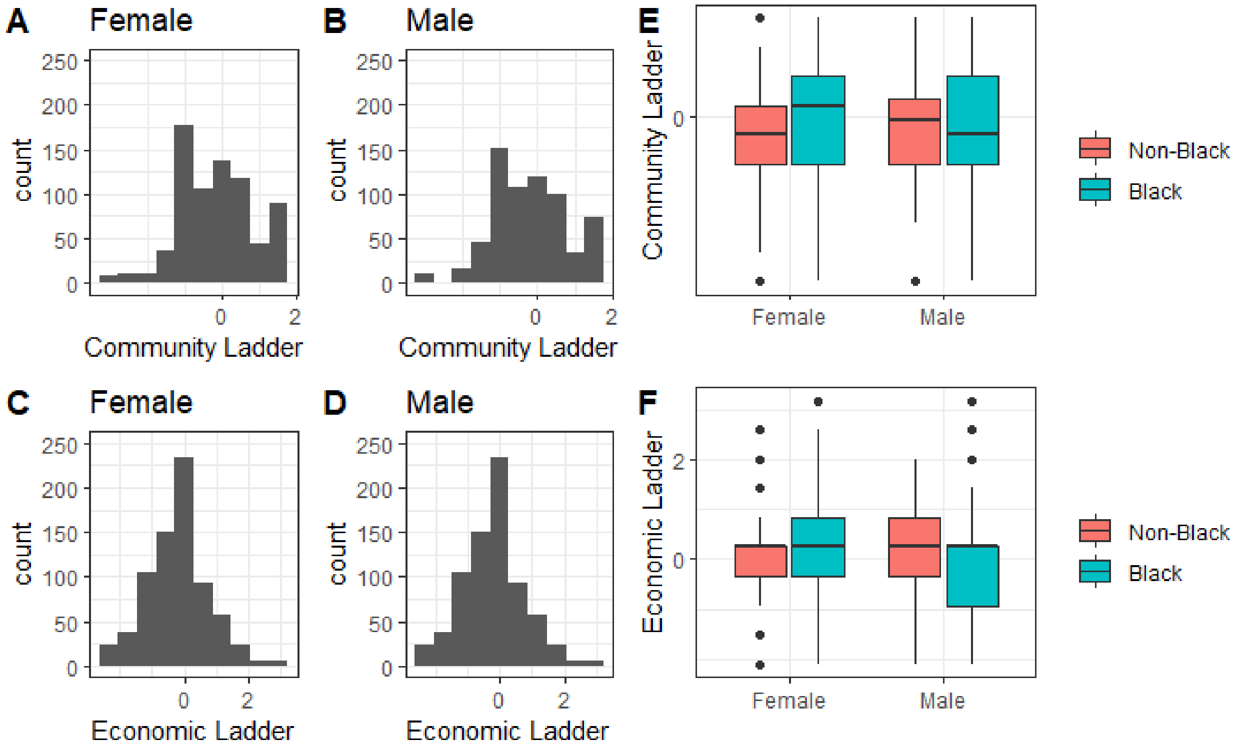
Supplementary Figure 7.2 Distribution of subjective social status in Guatemala



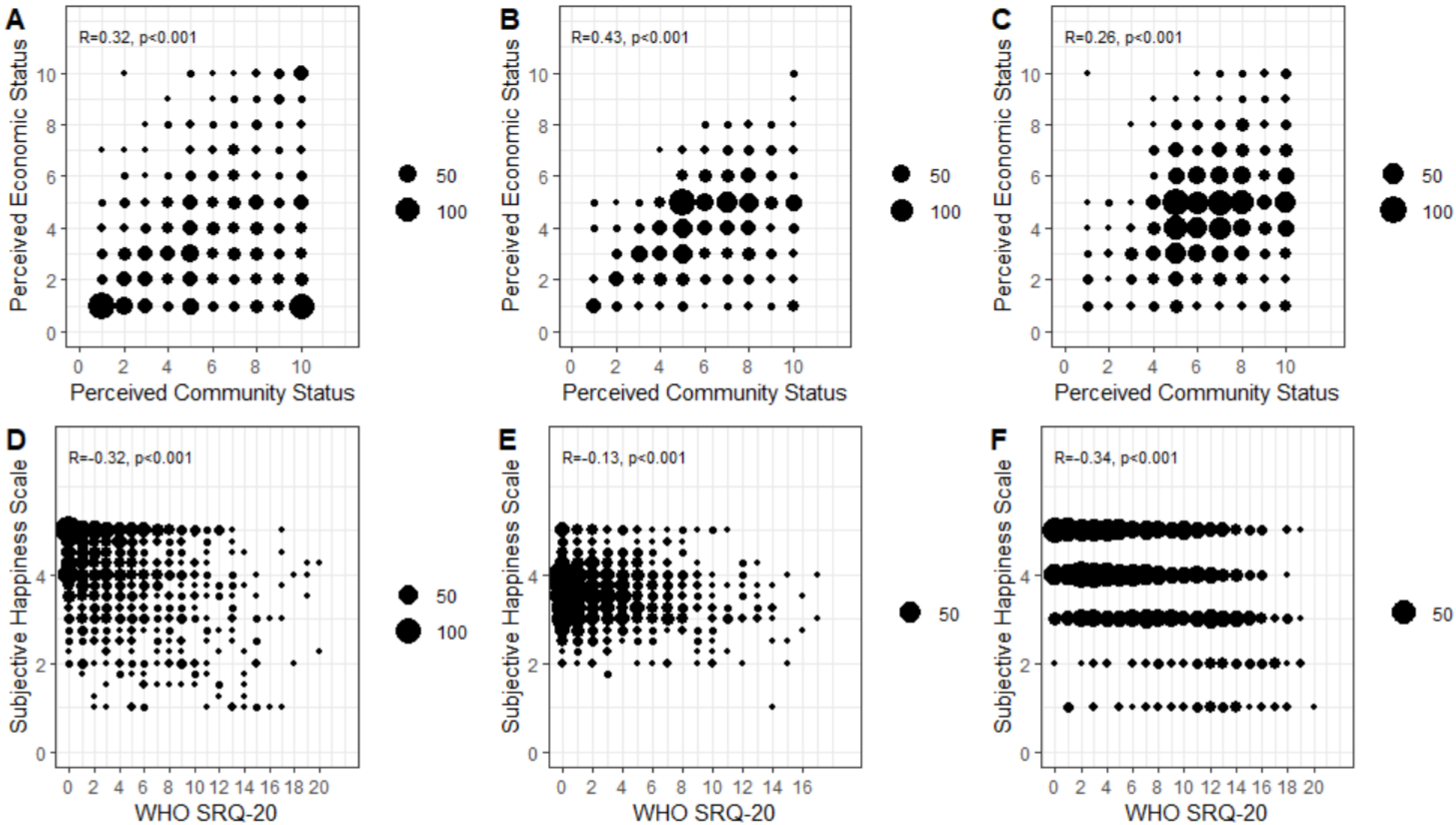
Supplementary Figure 7.3 Distribution of subjective social status in Philippines



Supplementary Figure 7.4 Distribution of subjective social status in South Africa

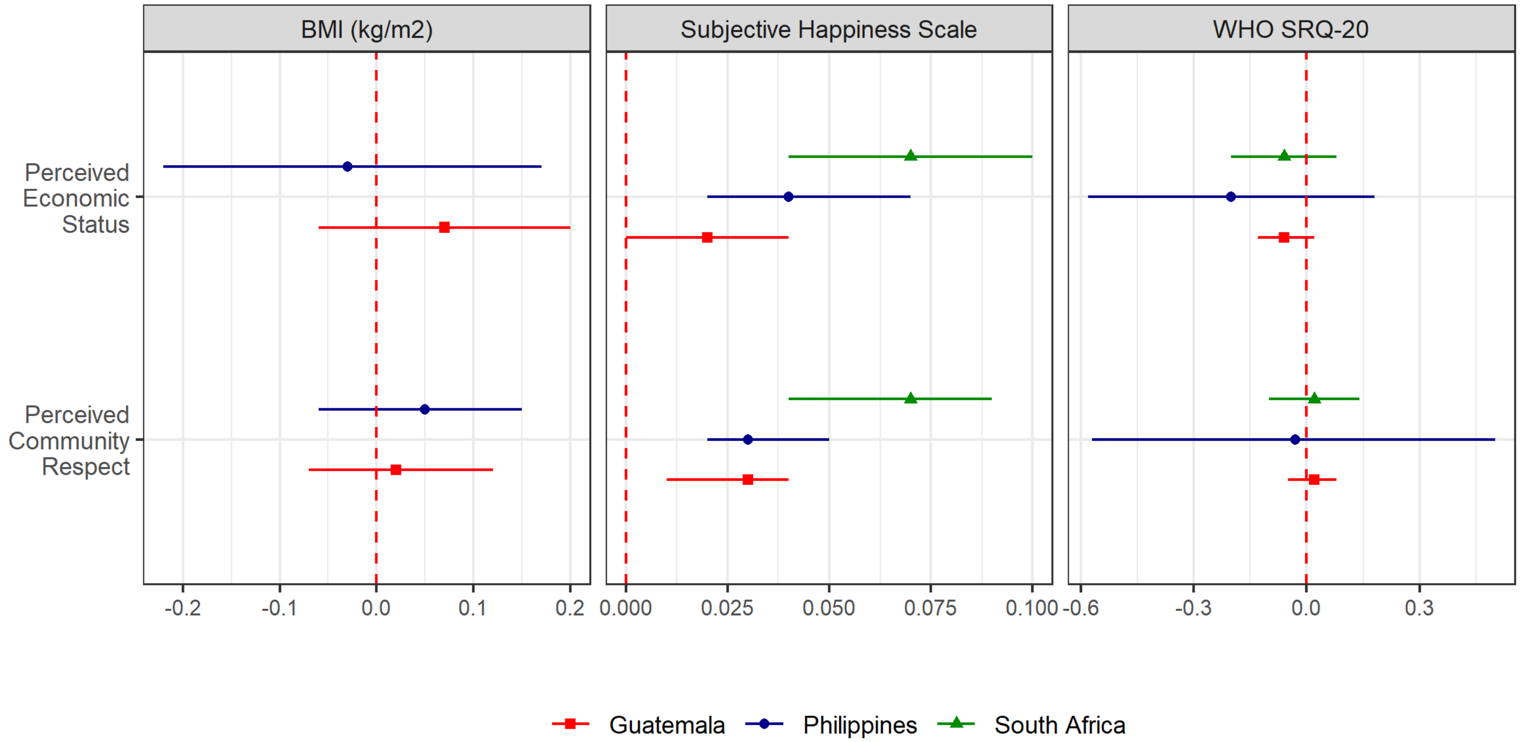


Supplementary Figure 7.5 Bivariate association of self-reported measures in three LMIC birth cohorts

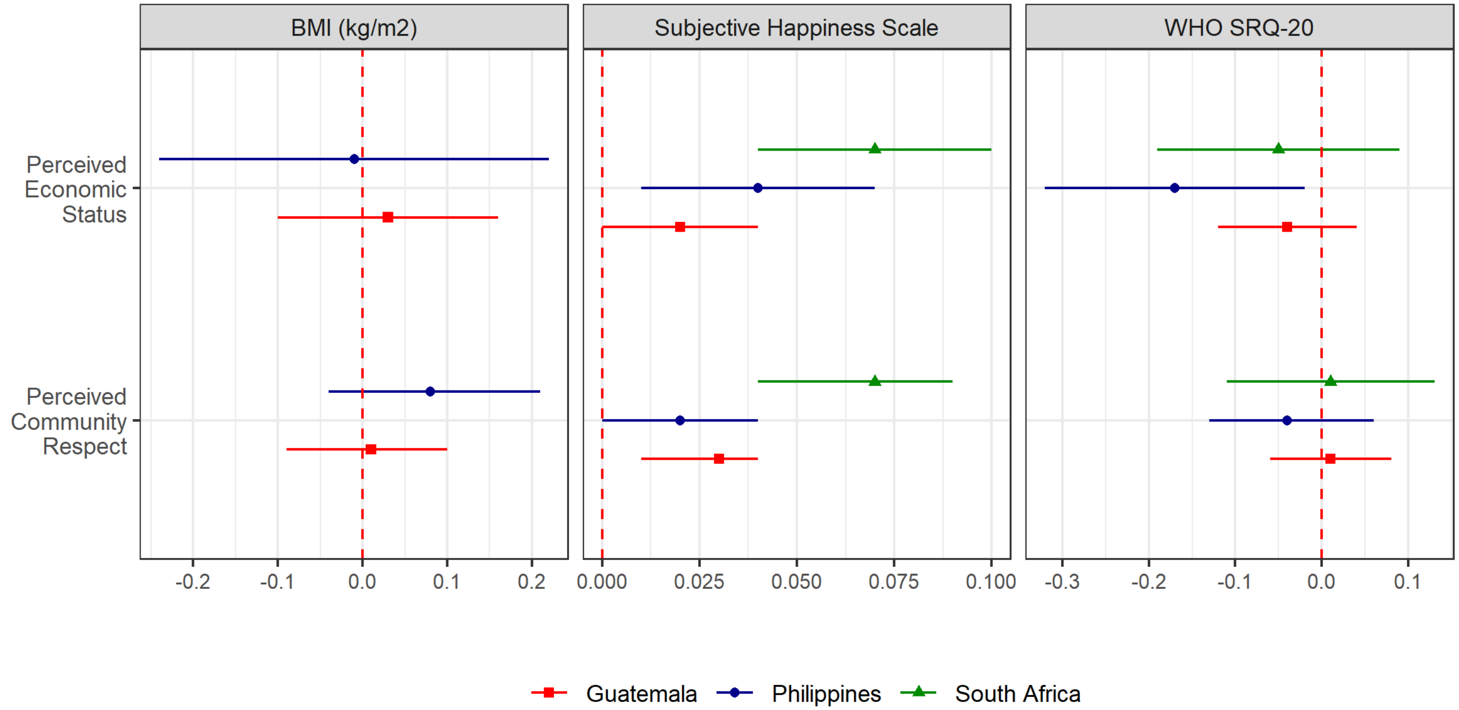


Panels A-C are for Guatemala, Philippines and South Africa respectively. Panels D-F are for Guatemala, Philippines and South Africa respectively.

Supplementary Figure 7.6 Linear regression after adjusting for life course wealth measures for 3 cohorts x 3 outcomes x 2 SSS measures



Supplementary Figure 7.7 Linear regression after inverse probability censoring weights for 3 cohorts x 3 outcomes x 2 SSS measures



Supplementary Table 7.1 Baseline characteristics by participation status in adulthood

	Guatemala			Philippines			South Africa	
	Died	**Did not respond**	**Participated**	**Died**	**Did not respond**	**Participated**	**Did not respond or Died**	**Participated**
N	**385**	**749**	**1258**	**287**	**1470**	**1323**	**1880**	**1393**
Maternal schooling	0 [0, 2]	1 [0, 2]	1 [0, 2]	6 [4, 7]	7 [6, 10]	6 [5, 9]	9 [9, 11.5]	9 [9, 11.5]
Maternal age	27.5±7.7	26.8±7.3	27.0±7.1	26.4±6.6	26.0±5.8	26.5±6.1	26.1±5.9	25.8±6.3
Wealth in childhood	-0.1±0.9	<0.1±0.8	-0.1±0.9	-0.3±0.8	0.1±1.1	-0.1±0.9	0.1±1.0	<0.1±0.8
Male	58.4%	59.3%	44.6%	61.8%	50.5%	53.9%	49.5%	47.4%
Birth order	4 [2, 4]	4 [2, 4]	4 [2, 4]	3 [2, 4]	3 [2, 4]	3 [2, 4]	2 [1, 3]	2 [1, 3]
Atole supplementation	55.6%	52.6%	52.5%					
Rural residence				26.8.1%	18.6%	28.0%		
Black							71.1%	88.4%

Supplementary Table 7.2 Regression coefficients for effect modification by sex

		Guatemala (INCAP) N = 1258		**Philippines (CLHNS) N = 1323**		**South Africa (Birth to Twenty plus) N = 1393**	
Effect modification by sex	**Contrast**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**
Perceived Community Respect							
Body Mass Index (kg/m^2)	Female	-0.04 (-0.17, 0.10)	45.78, p = 0.011	-0.03 (-0.26, 0.20)	22.21, p = 0		
	Male	0.08 (-0.07, 0.22)		0.09 (-0.04, 0.22)			
	Difference	0.11 (-0.09, 0.32)		0.13 (-0.14, 0.39)			
Subjective Happiness Scale	Female	0.03 (0.01, 0.05)	0.33, p = 0.574	0.04 (0.01, 0.07)	0.14, p = 0.713	0.05 (0.02, 0.09)	1.2, p = 0.273
	Male	0.02 (-0.00, 0.04)		0.03 (0.01, 0.04)		0.08 (0.04, 0.12)	
	Difference	-0.01 (-0.04, 0.02)		-0.01 (-0.04, 0.02)		0.03 (-0.03, 0.08)	
SRQ-20	Female	0.00 (-0.09, 0.10)	6.07, p = 0.016	-0.01 (-0.15, 0.14)	2.24, p = 0.134	-0.04 (-0.21, 0.12)	1.08, p = 0.299
	Male	0.05 (-0.03, 0.13)		-0.04 (-0.13, 0.06)		0.08 (-0.09, 0.24)	
	Difference	0.05 (-0.08, 0.17)		-0.03 (-0.20, 0.14)		0.12 (-0.11, 0.35)	
Perceived Economic Status							
Body Mass Index (kg/m^2)	Female	-0.03 (-0.20, 0.13)	78.86, p = 0	-0.35 (-0.67, -0.02)	189.46, p = 0		
	Male	0.19 (-0.04, 0.41)		0.18 (-0.05, 0.40)			

	Difference	0.22 (-0.06, 0.50)		0.52 (0.15, 0.90)			
Subjective Happiness Scale	Female	0.04 (0.01, 0.06)	3.21, p = 0.074	0.04 (-0.00, 0.08)	0.02, p = 0.875	0.10 (0.05, 0.14)	2.85, p = 0.091
	Male	-0.01 (-0.04, 0.03)		0.05 (0.02, 0.07)		0.05 (-0.00, 0.10)	
	Difference	-0.05 (-0.09, -0.00)		0.01 (-0.04, 0.05)		-0.05 (-0.11, 0.02)	
SRQ-20	Female	-0.13 (-0.23, -0.02)	83.01, p = 0	-0.28 (-0.50, -0.06)	-5540.81, p = 1	-0.13 (-0.34, 0.07)	1.32, p = 0.25
	Male	0.10 (-0.01, 0.22)		-0.10 (-0.25, 0.05)		0.02 (-0.16, 0.20)	
	Difference	0.23 (0.07, 0.39)		0.18 (-0.07, 0.43)		0.15 (-0.11, 0.42)	

Supplementary Table 7.3 Regression coefficients for effect modification by schooling

		Guatemala (INCAP) N = 1258		**Philippines (CLHNS) N = 1323**		**South Africa (Birth to Twenty plus) N = 1393**	
Effect modification by schooling	**Contrast**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**
Perceived Community Respect							
Body Mass Index (kg/m^2)	SSS at mean years	0.01 (-0.09, 0.11)	4.05, p = 0.451	0.06 (-0.07, 0.18)	11.05, p = 0.001		
	SSS at mean years + 1 y	0.02 (-0.09, 0.13)		0.07 (-0.07, 0.21)			
	Difference	0.01 (-0.02, 0.03)		0.01 (-0.02, 0.04)			
Subjective Happiness Scale	SSS at mean years	0.03 (0.01, 0.04)	0.53, p = 0.468	0.03 (0.02, 0.04)	0.14, p = 0.708	0.07 (0.04, 0.09)	0.09, p = 0.771
	SSS at mean years + 1 y	0.02 (0.01, 0.04)		0.03 (0.01, 0.04)		0.07 (0.04, 0.10)	
	Difference	-0.00 (-0.01, 0.00)		-0.00 (-0.01, 0.00)		0.00 (-0.02, 0.02)	
SRQ-20	SSS at mean years	0.03 (-0.03, 0.09)	34.38, p = 0	-0.03 (-0.11, 0.06)	-20.45, p = 1	0.00 (-0.12, 0.12)	2.27, p = 0.132
	SSS at mean years + 1 y	0.05 (-0.02, 0.11)		-0.03 (-0.11, 0.06)		-0.05 (-0.20, 0.10)	
	Difference	0.02 (-0.00, 0.03)		-0.00 (-0.02, 0.02)		-0.05 (-0.12, 0.02)	
Perceived Economic Status							
Body Mass Index (kg/m^2)	SSS at mean years	0.05 (-0.09, 0.18)	5.9, p = 0.411	-0.04 (-0.24, 0.17)	26.74, p = 0		
	SSS at mean years + 1 y	0.05 (-0.09, 0.20)		-0.06 (-0.29, 0.16)			

	Difference	0.01 (-0.03, 0.04)		-0.03 (-0.08, 0.02)			
Subjective Happiness Scale	SSS at mean years	0.02 (-0.00, 0.04)	3.48, p = 0.062	0.04 (0.02, 0.07)	0.02, p = 0.898	0.07 (0.04, 0.10)	0, p = 0.957
	SSS at mean years + 1 y	0.01 (-0.01, 0.03)		0.04 (0.02, 0.07)		0.07 (0.03, 0.11)	
	Difference	-0.01 (-0.01, -0.00)		-0.00 (-0.01, 0.01)		0.00 (-0.02, 0.02)	
SRQ-20	SSS at mean years	-0.04 (-0.12, 0.04)	10.51, p = 0.001	-0.18 (-0.31, -0.04)	-1411.14, p = 1	-0.04 (-0.19, 0.10)	1.15, p = 0.283
	SSS at mean years + 1 y	-0.03 (-0.11, 0.05)		-0.20 (-0.34, -0.05)		-0.00 (-0.17, 0.16)	
	Difference	0.01 (-0.01, 0.03)		-0.02 (-0.05, 0.01)		0.04 (-0.04, 0.12)	

Supplementary Table 7.4 Regression coefficients for effect modification by wealth in adulthood

		Guatemala (INCAP) N = 1258		Philippines (CLHNS) N = 1323		South Africa (Birth to Twenty plus) N = 1393	
Effect modification by wealth	**Contrast**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**	**Coefficient**	**LRT result**
Perceived Community Respect							
Body Mass Index (kg/m^2)	SSS at mean wealth	0.01 (-0.09, 0.11)	2.41, p = 0.396	0.06 (-0.07, 0.19)	16.52, p = 0		
	SSS at mean wealth + 1 unit	0.01 (-0.14, 0.15)		0.11 (-0.10, 0.32)			
	Difference	-0.00 (-0.10, 0.09)		0.05 (-0.07, 0.17)			
Subjective Happiness Scale	SSS at mean wealth	0.03 (0.01, 0.04)	0.04, p = 0.849	0.03 (0.02, 0.05)	0.04, p = 0.845	0.07 (0.04, 0.09)	0.34, p = 0.563
	SSS at mean wealth + 1 unit	0.02 (0.00, 0.05)		0.03 (0.01, 0.05)		0.07 (0.04, 0.11)	
	Difference	-0.00 (-0.02, 0.01)		-0.00 (-0.02, 0.01)		0.01 (-0.02, 0.04)	
SRQ-20	SSS at mean wealth	0.04 (-0.03, 0.10)	75.49, p = 0	-0.02 (-0.10, 0.06)	1.45, p = 0.229	0.00 (-0.11, 0.12)	3.02, p = 0.082
	SSS at mean wealth + 1 unit	0.12 (0.03, 0.21)		0.00 (-0.12, 0.13)		-0.09 (-0.26, 0.08)	
	Difference	0.08 (0.02, 0.15)		0.02 (-0.06, 0.10)		-0.10 (-0.21, 0.01)	
Perceived Economic Status							
Body Mass Index (kg/m^2)	SSS at mean wealth	0.04 (-0.09, 0.18)	28.79, p = 0.1	-0.03	5.12, p = 0.035		

				(-0.23, 0.18)			
	SSS at mean wealth + 1 unit	-0.01 (-0.22, 0.19)		-0.06 (-0.39, 0.26)			
	Difference	-0.06 (-0.20, 0.08)		-0.04 (-0.24, 0.17)			
Subjective Happiness Scale	SSS at mean wealth	0.02 (-0.00, 0.04)	0, p = 0.966	0.04 (0.02, 0.07)	0.06, p = 0.811	0.07 (0.04, 0.11)	1.81, p = 0.179
	SSS at mean wealth + 1 unit	0.02 (-0.01, 0.05)		0.04 (0.01, 0.07)		0.09 (0.05, 0.13)	
	Difference	-0.00 (-0.02, 0.02)		-0.00 (-0.02, 0.02)		0.02 (-0.02, 0.05)	
SRQ-20	SSS at mean wealth	-0.04 (-0.12, 0.04)	3.8, p = 0.053	-0.17 (-0.30, -0.04)	-1148.87, p = 1	-0.05 (-0.20, 0.09)	0.01, p = 0.925
	SSS at mean wealth + 1 unit	-0.02 (-0.13, 0.10)		-0.17 (-0.35, 0.00)		-0.06 (-0.26, 0.14)	
	Difference	0.03 (-0.05, 0.10)		-0.00 (-0.11, 0.11)		-0.01 (-0.14, 0.13)	

Chapter 8 Discussion and Next Steps

This dissertation aimed to track the progress in material capital, specifically wealth, over the life course of individuals in low- and middle-income countries and its association with health and wellbeing. The main findings from this dissertation are that (i) material living standards improved for five birth cohorts over their life course, (ii) the rate of change in living standards varied between individuals, (iii) maternal and attained schooling predicted future wealth mobility, (iv) childhood wealth and wealth mobility at all life stages were associated with intelligence but only mobility in the most recent life stage was associated with psychological distress and happiness, and (v) subjective social status was associated with happiness but not body mass index or psychological distress.

Despite economic recessions and slowing growth globally, life has improved for much of the world's population over time (1). The improvements in standard of living, as measured by possession of durable assets and housing characteristics, were previously captured over the last three decades using comparative analysis of the Demographic and Health Surveys (2-4). Consistent with these findings, the results from the five birth cohorts of the COHORTS collaboration that had collected data on standards of living showed that living standards improved for everyone in well-characterized communities over time (**Chapter 4**). However, in the absence of longitudinal data, it was impossible to know if the rate of improvement in standard of living was similar for those belonging to the same community. Our results (**Chapter 6)** showed that there is no single growth trajectory for material standards of living. We infer the latter finding from conditional wealth having non-zero variance at all life stages for four cohorts analyzed. As described previously, variance in conditional wealth is a marker of relative wealth mobility within the cohort (**Chapter 5**). Non-zero variance therefore implies positional mobility among the cohort members and different rates of growth. Our results also (**Chapter 6**) showed that relative wealth mobility, beyond what is predicted by early life SEP, was predicted by maternal and own attained schooling in school-age (6 to 17y), and attained schooling (among other factors) in adulthood (18 to 36y).

Under the assumption that early life socio-economic position was a fundamental cause of health disparities in adulthood, we estimated the role of relative wealth mobility in other life stages with health. Previous research on life course epidemiology of body mass index, intelligence, psychological distress and wellbeing showed that trajectories were determined to a large extent in childhood and early adolescence – implying the importance of the life stage as a sensitive period for adult health and wellbeing (**Chapter 2**). Our results (**Chapter 6**) did not show consistent findings for BMI, in line with the complexities of age-period-cohort effects across countries in the nutrition/obesity transition framework that we discussed in **Chapter 2**. However, our results were consistent across the birth cohorts studied for intelligence, psychological distress and wellbeing in adulthood. We found that there was a role for relative wealth mobility beyond wealth in childhood for these outcomes. Wealth mobility over the life course as well as schooling was predictive of intelligence. Upward wealth mobility between late adolescence and early adulthood was associated with lower psychological distress and higher happiness. These findings are consistent with studies of lottery winners and randomized experiments such as the Moving to Opportunity study, that showed favorable outcomes among the beneficiaries.

Research on subjective social status and health has previously shown one's own evaluation of prestige within a community may be associated with health and human capital through mechanisms such as stress pathways (endocrine, neuroendocrine), perceptions of shame or guilt. However, as highlighted in **Chapter 7**, these associations are susceptible to measurement error and unmeasured confounding from life course SEP and life satisfaction. Although we are not able to address the former, prospectively collected data from three birth cohorts allowed us to attempt addressing the latter. Our results were consistent across the three cohorts that subjective social status is associated with happiness, a finding that has been reported in other settings (**Chapter 7**). We find that subjective social status captures SEP-health associations that are not captured by other 'objective' indicators such as wealth or schooling. However, intervening on subjective social status to improve wellbeing is complex and understudied and potential pathways may include shame and guilt.

Public health implications

Standards of living improved over time for most of the world's population. However, given the rising wealth inequality in many parts of the world and the inverse association of inequality with upward social mobility, upward social mobility may decrease further than today. Moreover, the socio-economically vulnerable were affected disproportionately during the COVID-19 pandemic in terms of loss of employment, morbidity and mortality. In an environment of downward social mobility, the public health and policy implications of this research are twofold.

First, existing interventions to improve access and quality of schooling ought to be strengthened. Better schooling would result in intergenerational advantages in health and wellbeing (**Chapter 2,** see section on **Human capital and health**) for its beneficiaries as well as access to better information and eligibility for specialized jobs. However, as shown in the Fair Progress report detailed in **Chapter 2**, although intergenerational schooling has improved in LMICs, this did not translate uniformly to better job market opportunities. More schooling may include not only greater number of years in more traditional forms of school, but also vocational training and educational opportunities to upskill those whose jobs are threatened by automation, closures and outsourcing. A policy framework that aims to improve schooling should also tackle structural factors that prevent job creation. Given that this dissertation did not study the macroeconomics of economic policy, schooling and employment, I do not comment on this further.

Second, investments in mental health would be important in alleviating the health implications of downward relative mobility and in halting the progress of cardiovascular diseases (5). Such interventions may include ensuring access to mental health services at the community level in late adolescence and early adulthood as well as social safety nets (e.g. easy-to-avail unemployment benefits). The syndemics of depression and cardiovascular diseases may be a pertinent problem globally as economic growth slows, automation slows job creation, wealth inequality widens and social mobility decreases (6, 7). These global trends are occurring while the world is threatened by climate change and the possibility of future pandemics (such as COVID-19) resulting from human encroachment of disease reservoirs. This requires us to rethink existing models of economic growth (8-10). The financing of interventions requires solutions that are beyond the scope of this dissertation. Major redistributive policies such as higher income taxes or wealth taxes on the super-rich have low political mileage in LMICs such as India (11-13), and in high-income countries such as USA (14). In their absence, as suggested by Leach et.al, a political economy focusing on "mutual solidarity and care" as an important principle may help us design better interventions.

Limitations and potential solutions

Below, I discuss some conceptual, methodological and data limitations that are applicable to the reported findings.

1. Studies of wealth trajectories using temporally harmonized indices are susceptible to ceiling effects (**Chapter 4**). Alternatively, these indices may suffer from truncation, wherein they may not be able to differentiate between the wealthy and very wealthy, and between the poor and very poor. However, this limitation applies to all asset-based measures and expenditure instruments that allow large-scale data collection.

2. We observed imperfect correlations (rho < 1) between the normative cross-sectional or urban-rural stratified indices versus temporally harmonized indices. The associations of conditional wealth with health that are small in magnitude may therefore be due to random error. Methods to correct for this measurement error such as regression calibration may be useful (15). An alternate conceptualization of using cross-sectional indices instead of harmonized indices to create conditional wealth would ignore the mean (growth in wealth) and variance (changes in inequality) of life course wealth trajectories (**Chapter 5**).

3. By the nature of the assumption, we can never prove that our data is missing at random. High rates of attrition are common in cohort studies, especially birth cohorts from LMICs. Our analysis of attrition in **Chapters 4 to 7** showed no systematic loss to follow-up. However, our methods to correct for this (inverse probability of attrition weighting, multiple imputation) may be inadequate in the absence of covariates that may predict missingness rely on the missing at random assumption. Seaman et.al. proposed that a strategy of using IPW and MI are valid under the correct specification of the analysis and imputation models (16). Although we adjusted for all available covariates (analysis model), our imputation model may be incorrectly specified. However, given the nature of the cohorts (low- and middle- income country, migration for employment and schooling etc), it is challenging to improve on this without more data than is currently available to us.

4. Our lack of data on wealth at different life stages on the INCAP cohort prevents us from aligning our findings on relative wealth mobility (**Chapter 6**) with Ford et.al.'s findings, and our previous findings using INCAP data (17, 18). Ford et.al. showed that trajectories of BMI over the life course in men and women from the INCAP cohort from Guatemala separated in early life, and was associated with childhood wealth. The cohort used for the trajectory analysis from INCAP consisted of those born between 1962 and 1977, while the cohort used for the relative wealth mobility analysis consisted only of those born between 1970 and 1975. The associations of childhood wealth with adult BMI were negative in the relative wealth mobility analysis. However, childhood wealth was positively associated with the high BMI trajectory in Ford et.al. When we repeated our analysis with BMI for Guatemala, we observed a similar negative association between childhood wealth (-1.45 kg/m^2 per unit wealth, 95%CI: -2.72, -0.18) and a

positive association with adult wealth (0.58 kg/m^2 per unit wealth, 95%CI: -0.31, 1.48) after adjusting for the same set of early life and adult covariates as the relative wealth mobility analysis. These results were robust to collinearity (rho = 0.28) between the wealth measures. Our findings from Cebu Longitudinal Health and Nutrition Survey from the Philippines reassures us of our methodology. Slining et.al. also showed that infant trajectories of BMI were predicted by household wealth in childhood and in turn, predicted adult body composition (19). These results were consistent, under the obesity transition framework, with results from US and Germany that showed tracking of high BMI from infancy to adulthood among low SEP individuals and disadvantaged ethnic minorities (20). We observed positive associations with childhood wealth in both the trajectory analysis and relative wealth mobility among CLHNS participants. Additionally, the trajectory analysis using the CLHNS study did not adjust for life course wealth measures.

5. Our findings from three birth cohorts on the association of subjective social status with psychological distress do not align with our results using INCAP data (21) The reported associations from the analysis with INCAP cohort (1962-1977) alone did not adjust for life satisfaction and other adult covariates (marital status etc), which may predict subjective social status (22).

6. Finally, our outcomes for the analysis of relative wealth mobility (**Chapter 6**) and subjective social status (**Chapter 7**) were measured cross-sectionally with adult SEP. Attained schooling and wealth mobility over the life course predicted intelligence in adulthood. However, as noted before in **Chapter 6**, these associations are susceptible to reverse causality that is consistent with the reciprocal relationship observed by developmental psychologists previously (23). We believe

that our reported associations of relative mobility with happiness and psychological distress are true, and not driven by reverse causality since previous research reports health selection (health determines SEP) operates primarily in childhood and adolescence, and not in early adulthood and middle adulthood when our outcomes were measured (24, 25).

Strengths and Innovations

Despite the limitations listed in the individual chapters, and those identified above, the results have many strengths – driven primarily by the life course data available.

1. Consistently-collected data over the life course on assets and housing characteristics allowed us to develop temporally-harmonized asset indices. Such indices have numerous advantages (as identified in **Chapters 4 and 5**). Our results also showed that the harmonized index was robust to dropping assets, dropping survey years, and to alternate statistical methodologies (such as exploratory factor analysis and multiple correspondence analysis). The extension of the methodology of International Wealth Index, previously used in serial cross-sectional surveys, allows us to study an individual wealth over the life course.

2. Conditional wealth allows identifying stages in the life course when relative wealth mobility predicts health disparities. This is a methodological extension of the approach used to identify sensitive periods of anthropometric growth.

3. As part of the relative wealth mobility analysis, we carried out the harmonization of survey rounds across four birth cohorts. This allows comparability across cohorts that vary in year of birth and period effects. We observed consistent results across cohorts, allowing us to generalize

our findings of the association of relative wealth mobility with schooling, intelligence, psychological distress and happiness.

4. Subjective social status, anthropometry, psychological distress, intelligence and happiness were collected using the standardized survey instruments in 2017-18 for Guatemala, Philippines and South Africa. This allows us to exclude error from using different instruments across settings, further reinforcing our finding that subjective social status is associated with happiness, but not distress or body mass index.

Summary

In the absence of life course data, it is impossible to understand the dynamics of mobility in wealth for individuals in LMICs. This body of research suggests that trajectories of wealth over a period of 20 to 50 years were indeed distinct for individuals from well-characterized birth cohorts, and could not be predicted entirely by past wealth. Relative wealth mobility in school-age, late adolescence and early adulthood was associated with intelligence, health and wellbeing, highlighting the importance of social safety nets beyond childhood. A new policy framework that strengthens focus on schooling and creating job opportunities as well as extending mental health coverage and social safety nets is important. The former provides opportunities for fair progress while the latter may alleviate consequences of downward mobility Such interventions are critical as we are living in a period of slowing economic growth, rising wealth inequality and low social mobility.

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