An Agricultural Wealth Index for Multidimensional Wealth Assessments

Joseph Hackman[1*], Daniel Hruschka[2], Mariya Vizireanu[3]

1. University of Utah, Department of Anthropology

2. Arizona State University, School of Human Evolution and Social Change

3. Loyola Marymont University, Center for the Study of Los Angeles (StudyLA)

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*Corresponding Author:

Joseph.Hackman@utah.edu

DEPARTMENT OF ANTHROPOLOGY

260 S. CENTRAL CAMPUS DRIVE, RM 4625

SALT LAKE CITY, UT 8411

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Abstract

Social scientists have increasingly used asset-based wealth scores, like the DHS wealth index, to assess economic disparities. However, current indices primarily capture wealth in globalized market economies, thus ignoring other forms of prosperity, such as success in agricultural activities. Using a simple extension to the standard estimation of the DHS Wealth Index, we describe procedures for estimating an Agricultural Wealth Index (AWI) that complements market-based wealth indices by capturing household success in agricultural activities. We apply this procedure to household data from 129 DHS surveys from over 40 countries with sufficient land and livestock data to estimate a reliable and consistent AWI. We assess the construct validity of the AWI using benchmarks of growth in both adults and children. This alternative measure of wealth provides new opportunities for understanding the causes and consequences of wealth inequality, and how success along different dimensions of wealth creates different social opportunities and constraints for health and well-being.

Key Findings

1. Common asset-based wealth indices like the DHS Wealth Index do not capture household prosperity in the agricultural sector.

2. Asset data in the DHS can be used to estimate a consistent and reliable Agricultural Wealth Index (AWI) that complements standard market-based indices.

3. The AWI showed meaningful associations with indicators of growth in a broad range of contexts.

Introduction

A key concern in social science and population health is how economic status and inequality shapes individual development, behavior, and health (Link and Phelan 1995). For this reason, social scientists and policymakers have maintained a long-standing interest in estimating the economic status of individuals and households (Filmer and Pritchett 2001; Gwatkin 2000).

In high-income populations, researchers commonly use income and expenditures to track economic resources. However, in low-resource settings where measuring income can be more costly and prone to error, researchers have relied on wealth indices constructed from easy to collect data on assets, household construction, and access to services to capture household access to resources (Filmer and Pritchett 2001; Howe et al. 2012; Hruschka, Gerkey, and Hadley 2015; Kaiser, Hruschka, and Hadley 2017; Rutstein and Johnson 2004; Smits and Steendijk 2015; Filmer and Pritchett 1999).

Intended to capture the long-run economic capacity of a household, these indices, such as the Demographic and Health Survey's (DHS) Wealth Index, provide a cost-effective and robust assessment of economic capacity to study the effects of wealth inequality on health and demographic outcomes (Booysen et al. 2008; Fotso and Kuate-Defo 2005; Hruschka and Burger 2016; Rutstein and Staveteig 2014; Sahn and Stifel 2000; Smits and Steendijk 2015; Wagstaff 2000). Asset-based wealth indices show strong associations with growth and development (Krishna et al. 2015; Vollmer et al. 2014; Stevens et al. 2012), education (Filmer and Pritchett 1999), and fertility outcomes (Colleran and Snopkowski 2018) indicating they serve as meaningful proxies for household access to resources.

The DHS Wealth Index has become a staple in public and global health studies by providing detailed information about socioeconomic disparities in health status and use of health services (Carr 2004; Rutstein and Johnson 2004). The World Health Organization, World Bank, national governments, NGOs, and development agencies rely on these data to develop and evaluate targeted programs improving equity in health, nutrition, education, and reproductive services (Carr 2004; Chakraborty et al. 2016; Ergo et al. 2016; Ravallion 2007; WHO 2014). Additionally, these indices provide crucial data to researchers for testing theories about fundamental causes of health inequities around the world (Hadley, Maxfield, and Hruschka 2019; Hohmann and Garenee 2011; Houweling et al. 2007; Victora et al. 2018). Similar wealth indices have now been adopted for general use in a broad range of health monitoring surveys including UNICEF'S Multiple Indicator Cluster Survey (MICS), the AIDS Indicator Surveys, and Malaria Indicator Surveys (Rutstein and Johnson 2004; Rutstein 2008).

While such asset-based wealth indices have grown in popularity, an emerging literature has raised concerns that many indices rely on assets that privilege only certain forms of economic activity (Garenne 2015; Howe, Hargreaves, and Huttly 2008; Hruschka, Hadley, and Hackman 2017; Kaiser, Hruschka, and Hadley 2017; Lachaud et al. 2019; Rutstein 2008). For example, the DHS Wealth Index frequently reflects possession of goods

that are obtained primarily through cash-based transactions (e.g. TV, refrigerator, phone) or public services that may not be available to households that are only marginally engaged in cash economies (Bingenheimer 2007; Ferguson 1992; Guyer 1997; Manger 2000). However, in many low- and middle-income contexts, agricultural activity also contributes substantially to household production, such that success in the agricultural economy is likely a complementary indicator of economic well-being (BurnSilver 2016; Garenne 2015; Lawson et al. 2015; Little et al. 2008). Wealth indices that prioritize assets accrued through cash-based transactions can mask important sources of economic capacity and neglect crucial distinctions between individuals and households engaged in livelihoods outside of the cash economy. For example, a recent study of mental health in Haiti showed that a wealth index capturing agricultural success showed stronger associations with reduced anxiety and depressive symptoms than did a wealth index that captured success in the cash economy (Lachaud et al. 2019).

To address these shortcomings, researchers have proposed a number of possible remedies. The first solution is to include agricultural assets in the construction of wealth indices to capture greater diversity in livelihoods. Agricultural land and livestock holdings have increasingly become standard data collected by the DHS. However, most asset-based approaches still only estimate one dimension, thereby assuming that there is a single primary dimension that captures the diversity of ways in which households move from poverty to prosperity (Rutstein 2008). Moreover, if the majority of assets result from success in the cash economy, then this single dimension will reflect success in the cash economy even if some agricultural assets are included (Bingenheimer 2007; Hruschka, Hadley, and Hackman 2017)

Another solution is to construct separate indices for urban and rural populations (Rutstein 2008). However, dividing construction of indices by households identified as “urban” vs. “rural” raises a number of issues. First, the criteria by which households are defined as urban or rural is not always clearly specified. For example, the definition of rural and urban in DHS surveys is country-specific, which can vary from country to country, and is not included in survey reports. These definitions may vary substantially both across and within countries with definitions based on boundaries of political and administrative units, population size and density within a geographic region, or even on the presence or absence of non-agricultural activities, markets, and social services in enumeration areas (Levira and Todd 2017; Muzzini et al. 2008). Second, households in urban areas may be extensively involved in agricultural production either through urban agriculture or through ownership of agricultural assets outside the

city (Yitaye Alemayehu Ayenew; Maria Wurziger and Zollitsch 2007). Third, households in rural areas may also be extensively involved in a combination of agricultural and cash-based wage-labor production (Rigg 2006). Thus, simply constructing separate indices for rural and urban settings may still not capture multiple dimensions of wealth in a given setting, Indeed, Figure 1 illustrates how urban- and rural-specific indices provided in recent DHS datasets (n = 30) are still highly correlated with market goods (e.g. TV, refrigerator, car) but largely uncorrelated with key agricultural assets such as quantity of land or livestock.

[INSERT FIGURE 1]

A Multidimensional Model of Wealth Addresses the Limitations of Single-dimensional Wealth Indices.

In contrast to the unidimensional models of wealth that underly the most commonly used asset-based indices, a multidimensional model of wealth assumes households have multiple pathways for accumulating economic resources (Guyer 1997; Little et al. 2008; Manger 2000; Yitaye Alemayehu Ayenew; Maria Wurziger and Zollitsch 2007; Lachaud et al. 2019). Assuming multiple pathways for accessing resources opens new ways to approach the asset data used in constructing indices. Notably, data reduction techniques used in the construction of single-dimensional wealth indices can also be extended to estimate multiple dimensions. One analytic solution to the problems outlined above would be to explore second and third factors produced by correspondence analysis, with the assumption that these additional dimensions may reflect achievements along alternative livelihoods. Applying this approach to 6 countries from 3 world regions, Hruschka et al. estimated reliable, complementary measures of both success in cash economies and in agricultural economies (Hruschka, Hadley, and Hackman 2017). Both of these indices showed construct validity with independent positive associations with key indicators of nutrition and growth. A key strength of this approach is that it allows researchers to capture multidimensional variation in wealth while using existing data from current datasets. Furthermore, such multidimensional estimates of material wealth have permitted researchers to re-examine persistent puzzles in population health like the puzzling, positive associations between HIV and the DHS Wealth Index in sub-Saharan Africa (Bingenheimer 2007; Hadley, Maxfield, and Hruschka 2019; Shelton, Cassell, and Adetunji 2005). This counterintuitive finding suggested that wealth was a primary cause of behavioral risk for HIV. However, Hadley et

al found this positive association was only observed in the DHS wealth index, and an Agricultural Based Wealth index often showed significant negative association (Hadley, Maxfield, and Hruschka 2019). Thus, the link between wealth and HIV risk in Sub Saharan Africa depends critically on how wealth is measured.

Here, we extend the multidimensional estimation of wealth to the full range of datasets from The DHS Program (henceforth, DHS datasets) with detailed data on agricultural assets (i.e., land and livestock). For these datasets, we estimate an Agricultural Wealth Index (AWI) alongside a Market-based Wealth Index (MWI). Like the DHS wealth index, the latter index is characterized by the goods and services that households more frequently access through cash-based markets. A crucial point is that the AWI and MWI track achievement along different types of economic production which may or may not coincide with distinctions between urban and rural contexts. Focusing on livelihoods rather than contexts allows us to capture variation among households who are actively engaged in both types of production. Indeed, households who engage in agricultural production likely still participate in the cash economy to varying degrees (Rigg 2006; Yitaye Alemayehu Ayenew; Maria Wurziger and Zollitsch 2007). Estimating two dimensions allows us to capture the various and hybrid ways households accumulate wealth regardless of whether they live in the city or the countryside.

Additionally, estimating multiple indices simultaneously permits a clear interpretation of what it means for a household to own agricultural assets. As noted above, owning livestock and land can reflect both the accumulation of agricultural wealth as well as deprivation in the market economy. By estimating both the AWI and MWI simultaneously, we account for agricultural wealth accumulation partialling out accumulation of market wealth. This provides a significant advantage over attempts to build agricultural and market wealth indices independently (Colleran et al. 2015; Garenne 2015).

Methods

Developing the agricultural wealth index

Here, we outline a general procedure for estimating multiple dimensions of material wealth and selecting which dimensions best reflect success in the agricultural economy and which best reflect success in the market economy. We also demonstrate the construct validity of these complementary wealth measures across a broad range of countries, by showing independent and

positive associations of these two dimensions with key growth benchmarks, including adult BMI and child height-for-age.

Data

From the set of over 300 publicly available DHS surveys, we identified 131 surveys from 58 countries that have quantitative land variables and either yes/no variables for at least five types of livestock or counts for any livestock (Supplementary Table 1). Survey year ranged from 1993, one of the earliest DHS surveys to include livestock or land ownership, to 2018.

Variables for constructing the AWI

We used data typically employed in the creation of the DHS wealth index. This includes information about household construction, assets, and access to basic services. Nominal variables with more than two categories were dummy coded as a series of dichotomous variables. Count variables for livestock and land were recoded into a series of dummy variables indicating ranges of hectares or animal counts (see supplemental materials. This resulted in a total of 432 unique dichotomous variables across all surveys. Surveys ranged in the number of variables used from 73 to 195 (see supplemental materials for full list of asset variables).

Multiple correspondence analysis

To generate the multiple wealth dimensions, we applied a Multiple Correspondence Analysis (MCA) to each individual survey allowing up to 3 dimensions to be estimated (in SPSS) (Hruschka, Hadley, and Hackman 2017). The estimation procedure (MCA) is related to the principal components analysis (PCA) used to construct the one-dimensional DHS Index. However, MCA is better suited to handle nominal categorical data typical of the asset data collected by the DHS (Traissac et al. 2012; Howe et al. 2012; Poirier, Grépin, and Grignon 2019). Whereas the DHS Index takes the first, and often the most reliable dimension to serve as the wealth index, we examine the second and third dimensions produced as well. . Like many multidimensional data reduction techniques, the MCA procedure estimates a cloud of households in a multidimensional space based upon differences and similarities in the suite of assets owned. The procedure then estimates a number of dimensions running through the space that successively captures the most variance in asset ownership (Greenacre and Blasius

2006). Dimensions are scaled to have a standard deviation of 1, and the internal reliability of each dimension is reported using Cronbach's alpha.

Selecting and Anchoring Dimensions

Dimensions estimated by MCA do not have an inherent meaning or direction. To determine which dimension corresponds most clearly with market- or agricultural-based wealth, we followed the DHS protocol in using anchoring assets to facilitate interpretation. We selected variables that were common across all surveys that reflected market-based assets—ownership of improved toilet type, a television, a refrigerator, and a car or truck—as well as assets reflecting success in agricultural activities—hectares of land and number of livestock owned, converted to Total Livestock Units (TLUs) [see supplemental materials for TLU coding]. We used the correlation between these assets and the raw indices to select the appropriate dimensions for the MWI and the AWI and to set the direction of each index. The anchoring algorithm is outlined in detail in the supplemental materials.

Comparing wealth dimensions with physical growth

Next, to validate the indices, we examined the association between household MWI and AWI scores with adult BMI (93 surveys) and child HAZ (101 surveys)—two growth indicators which should be associated with economic capacity. We focused on women aged 40-49 as they normally show maximal associations between BMI and wealth (Hruschka, Hackman, and Stulp 2019; Hruschka, Hadley, and Brewis 2014; Hruschka and Hadley 2016). For child growth outcomes, we focused on 12-59 m old children as prior research has shown HAZ may not be a particularly reliable measure of nutrition among 0-11 m old (Hackman and Hruschka 2018; Wright 2000). Adult BMI was calculated as weight (kg)/height (m)2, and we excluded cases with values below 10 or above 80. Child height-for-age zscores (HAZ) were calculated based on the current World Health Organization's reference distributions, and cases with absolute z-scores greater than 6 SD were excluded.

The validation procedure employed a multilevel linear model. For BMI we controlled for age, urban residence, and education (None, primary, secondary, higher). For childhood HAZ we controlled for age in months, urban residence, sex, and mother's education. To account for established nonlinear effects of child age on HAZ, we center at 24 months – near the age at which HAZ stops declining with age—and include a spline variable

starting at 24 m (Leroy et al. 2014). The models included a random intercept for each study and allow the effects of MWI and AWI to vary across surveys. We also included an interaction term for urban/rural residence and each wealth index as a random effect to allow the strength and sign of the interactions to vary across surveys.

Results

MCA Results

Across all surveys the first dimension accounted for between 5% and 12 % (Mean inertia =7.4%, SD=1.4) of variance in the household assets, with the second and third accounting for an average of 3.2% (range=2.2%-5.6%, SD =0.5) and 2.4% (range=1.7%-3.7%, SD =0.4) respectively. The average internal reliability for the three dimensions were α_{D1}= 0.91 (SD =0.02), α_{D2}=0.80 (SD =0.03), and α_{D3}=0.72 (SD =0.04). These suggest that the second dimension on average reliably accounts for substantial differences in the clustering of household asset ownership.

Determining the MWI and AWI from the estimated dimensions

Using the anchoring assets, we selected the dimensions that best reflect the AWI and the MWI (see supplemental materials). The dimensions selected for the MWI showed strong positive associations with all market wealth anchoring variables (Figure 2 Panel A). In turn, the AWI dimensions showed strong positive associations with the agricultural anchoring variables (Figure 2 Panel B). The MWI captured much of the original DHS wealth index, with a mean correlation of r=0.90 (SD=0.16), while the AWI showed weak associations with the DHS wealth index (mean r =0.16, SD=0.23; Figure 2 Panel C). Finally, reliability estimates show the MWI has good internal reliability (mean Cronbach's α=0.91, SD=0.02), with lower, but still acceptable, reliability for the AWI (mean Cronbach's α =0.79, SD=0.03, Figure 2 Panel D).

[INSERT FIGURES 2 & 3]

Validation of the AWI

Consistent with the findings from Hruschka et al (2017) both the MWI and the AWI had a significant positive association with growth outcomes (Table

1). In both models, the MWI had a stronger effect on growth outcomes than the AWI, with the AWI effects approximately 20-28% of the size of the effect of MWI. The positive effect of AWI on BMI was primarily driven by positive associations in rural contexts, as the interaction shows much smaller effects of AWI in urban contexts (Figure 4). Similarly, the association of MWI with BMI were also stronger in rural environments. In rural areas, moving 5 SD across the distribution of AWI is associated with a 1.8 kg/m^2 increase in adult BMI, and moving 5 SD across the distribution of MWI is associated with an 8.8 kg/m^2 increase.

[INSERT TABLE 1]

For child growth, AWI had a significant positive effect on HAZ, with similar effects across both rural and urban contexts. Moving 5 SD across the AWI was associated with an average 0.4 SD increase in HAZ scores, and a 1.4 SD increase for 5 SD increase in MWI. Notably, the effect of AWI on growth varied substantially. Figure 4 presents the joint distribution of effects of MWI and AWI (Top), and the distribution of estimated effects across all surveys (Bottom). While a handful of the surveys showed negative associations of AWI with growth, the majority show largely positive associations of AWI with growth, particularly in rural areas. Furthermore, in some populations the effects of AWI were quite large. For example, in rural populations in Namibia 2007, Kenya 2009, Lesotho 2009, and Swaziland 2006 a 1 SD increase in AWI was associated with over a 1 kg/m^2 increase in BMI. For rural populations in Ghana 2008, Honduras 2006, Namibia 2007 and Pakistan 2018 a 1 SD increase in AWI was associated with 0.2 SD increase in HAZ. Indeed, in these populations, households at the ends of the AWI distribution (-2.5 SD to +2.5 SD) differed by 1 SD in HAZ.

For adult BMI, the survey-specific estimates of the effect of AWI were more consistently positive in rural samples. Indeed 88% of surveys showed positive associations of AWI with BMI in rural areas compared to 42% of urban samples. For child HAZ the distribution of survey-specific estimates for the effect of AWI were similar across both rural and urban contexts, with 86-87% of surveys showing positive effects in rural and urban contexts.

Overall, the effects of both wealth indices showed generally positive effects on measures of growth, indicating that both captured independent variation in household-level resources. Additionally, the correlation between the AWI effects on BMI and the AWI effects on HAZ is positive ($r=0.51$, $p<0.001$, $N=97$). This indicates that when AWI is more positively associated with

adult growth, it also shows more positive associations with child growth (supplemental materials Figure 6). Finally, supplemental analyses showed the effects sizes increased with more reliable dimensions (supplemental materials Figure 7).

[INSERT FIGURE 4]

Discussion

Asset-based wealth indices have provided an important means for assessing the relationship between economic resources and health and wellbeing in a broad range of contexts around the world. However, the unidimensional model of wealth underlying the construction of these indices, and the heavy bias toward market-based goods and services neglect other pathways by which households accumulate and access economic resources, most notably in the agricultural sector. By contrast, a multidimensional model of wealth assumes households have multiple pathways for economic achievement, and that these pathways can shape the types of assets and services a household has access to. Using data on agricultural assets from demographic and health surveys, we outlined a general procedure for estimating and interpreting multiple dimensions of material achievement that have clear interpretations as success in agricultural activities. Using this procedure, we were able to estimate an Agricultural Wealth Index (AWI) for 129 surveys that included sufficient data on land and livestock ownership. Furthermore, this AWI captured household economic capacity independently of the commonly used first dimension and showed biologically meaningful associations with growth indicators across a wide range of populations.

Given the prominence of the use of DHS data in the social science, the economics and development literature, global health, and policy literatures, the AWI provides a complementary tool for addressing a broad range of relevant questions. The primary strength of the DHS wealth index is that it provides a clear proxy for household access to resources with less data demands than income or consumption measures (Filmer and Pritchett 2001). The AWI draws on these strengths and extends the application of using asset-based indices. Using existing data, we estimate additional measures of resource access that capture meaningful variation among households. Indeed, this provides an approach to interpreting information that is effectively discarded when generating single-dimensional wealth indices. The approach permits finer-grained distinctions regarding

household livelihoods, and how resources are distributed within populations. Finally, while we used data sets as early as 1985, most DHS surveys collected after the year 2000 have the necessary data for estimating an AWI.

These findings also generate new questions and insights. While the association of AWI with growth outcomes were generally positive, they varied substantially across populations. What are the contextual factors that provide opportunities or obstacles for translating success in the agricultural sector into improved growth and nutrition? Minimally, agricultural accumulation provides a buffer against nutrition-related disease (Ferguson 1992; Little et al. 2008; Popkin 2014; Yitaye Alemayehu Ayenew; Maria Wurziger and Zollitsch 2007). How much of the effects of the AWI are due to direct consumption of agricultural production vs increasing the economic capacity of the household to meet nutritional needs through other means such as contributions to household income (Berinyuy and Fontem 2011)? Does agricultural accumulation shape a household's ability to invest in things other than nutrition, like increasing ability to access health care or educational services?

One theoretical objection to using a second dimension of wealth is based on the fungibility of income. Specifically, if income is treated as fungible, and assets are used as a proxy of income flows that can also be used to improve nutrition, then there should be no need to construct a second dimension. They key flaw in this reasoning is that the assumption that households have homogenous preferences. Specifically, a household's assets are a product of both fungible income flows and a household's needs and desires. Suppose one set of households prefer to acquire more land and animals with their income flows and another set of households prefer to build concrete walls and purchase consumer electronics. Also suppose that both sets of households care about translating some of their income flows into child and adult growth. If we focused only on the dimension that effectively captures concrete walls and consumer electronics, then we would miss income flows that have been translated into other kinds of wealth. Beyond this theoretical argument, the agricultural wealth index is empirically associated with physical growth. Thus, even though a second dimension may not seem theoretically necessary, it does seem to be practically useful for capturing differences in household investments in growth.

In addition to disparities in growth and nutrition, the AWI index may be useful in understanding or important demographic and health differences (Hadley, Maxfield, and Hruschka 2019; Lachaud et al. 2019). For example, the AWI may provide insights into the patterns of fertility change in many low- and middle-income countries. The fertility transition is often

characterized by a negative association between wealth and fertility. However, the reliance on wealth measures that reflect engagement in the wage-labor economy may obscure our understanding of how resources shape fertility. When and where might success in the agricultural sector lead to greater fertility, or greater declines in fertility is an important question for understanding causal factors in fertility decline (Garenne 2015; Colleran et al. 2015; Colleran and Snopkowski 2018).

Several caveats accompany use of this procedure. First, the anchoring algorithm worked well for most DHS surveys, but surveys that do not use these anchoring assets may require a different set of anchors. Here the first dimension was nearly always capturing variation among market-based engagement. This is not surprising given the suites of assets, household construction, and access to services the DHS surveys often consider. However, in populations that engage only minimally with outside markets, instead engaging primarily in a mixed agricultural and foraging economy, we might find that the first two dimensions reflect agricultural and foraging engagement, respectively. Second, while the land and livestock data are sufficient to estimate an AWI, the variables collected in these surveys still have smaller representation than market-economy assets. As noted in Hruschka et al 2017, this bias in asset data may underly the lower internal reliability of the AWI. Finally, in some instances, biplots of the 2 dimensions exhibited an “arch” or “horseshoe” effect whereby the households are distributed selectively in a curved shape. This is a well-known phenomenon, and there is considerable debate about whether to address it and how to address it (Wartenberg, Ferson, and Rohlf 1987; Peet et al. 1988). Researchers have proposed a number of techniques for estimating dimensions that are free from such effects, including detrended correspondence analysis and non-metric multidimensional scaling (Hill and Gauch 1980; Legendre and Gallagher 2001). Future work with the AWI should examine how sensitive results are to alternative techniques of estimating these dimensions.

Locally grounded work could provide insight into the types of assets or agricultural indicators that would provide more reliable estimates of economic capacity cultivated in agricultural activity (or other forms of economic activity). For example, diversity in livestock breeds owned by a household, or ownership of specific equipment needed for using modern pesticides or fertilizers, or even the types of crops cultivated could help discriminate subsistence producers from those engaged in commercial production.

A key benefit of the approach outlined here is that it uses existing data in many recent demographic and health surveys yet permits examination of

alternative forms of material wealth. Additionally, this approach addresses a long-standing concern in use of asset-based wealth indices regarding the interpretation of higher order components. Filmer and Pritchett (1999) acknowledged this issue in one of the first discussions of an asset-based wealth index,

> "There is a generic problem with principal components analysis. While it is relatively easy to interpret the first principle component, an intuitive explanation of the second and higher-order components is more problematic…. We do not know how to interpret this second principal component (especially in a consistent way across countries) and ignore it for now in an uneasy truce with the data (Filmer and Pritchett 1999: pg 89)".

Our approach helps to resolve this uneasy truce and outlines a path for developing a conceptually clear and consistent interpretation of higher-order components. Indeed, the development of the AWI provides scholars and policy makers a complementary tool for capturing the economic conditions of households that may appear homogenous through the lens of a unidimensional wealth index. In future work, the AWI should provide new opportunities for measuring economic capacity and poverty along different dimensions, for testing theories regarding the causes and consequences of wealth inequality, tracking how households engage in mixed-economic production, and how success along different dimensions creates opportunities and constraints for health and well-being.

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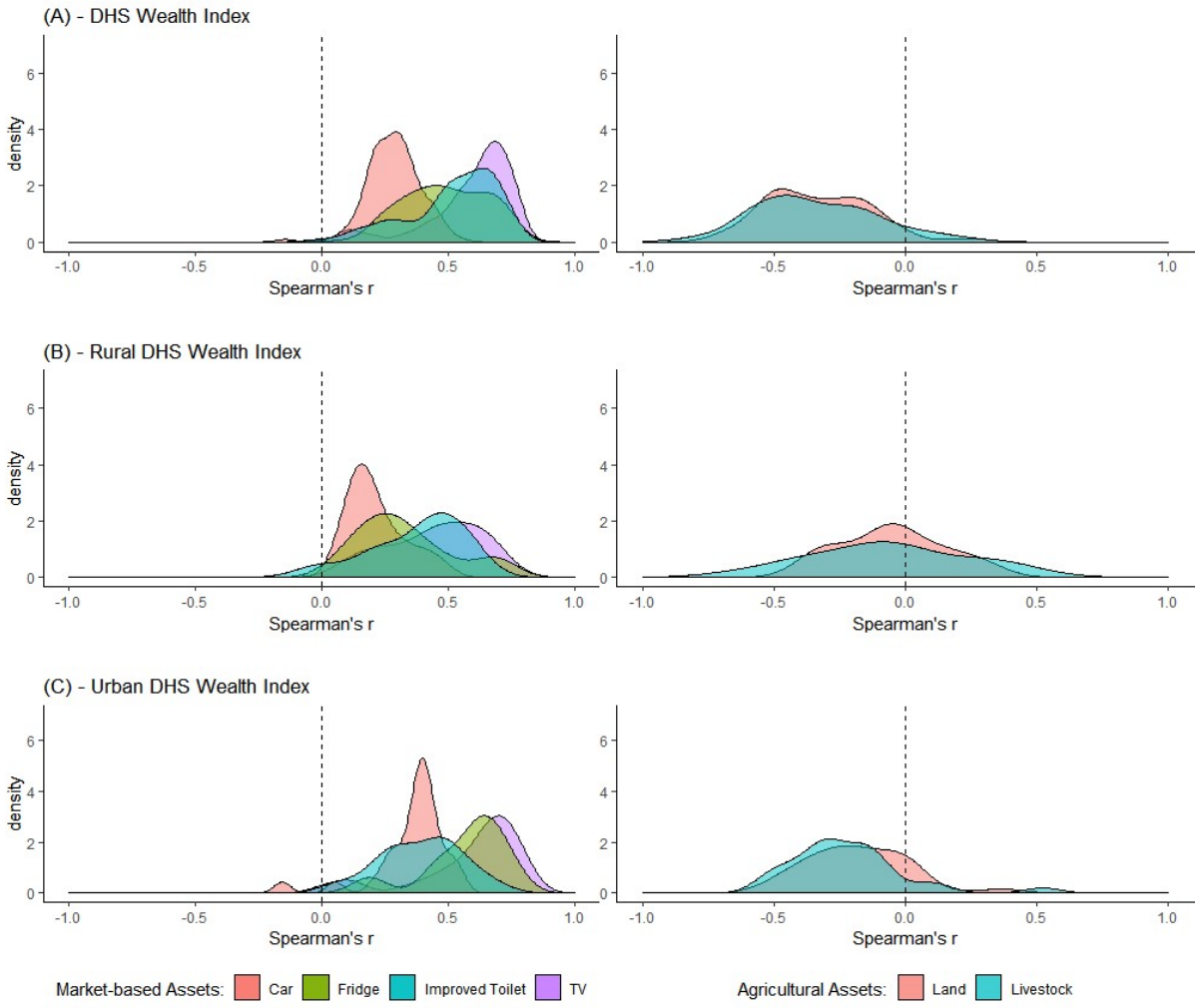

Figure 1. The distribution of correlation coefficients between key assets and the standard DHS Wealth Index Factor score (A); the Rural-specific DHS Wealth Index Factor score (B); and the Urban-specific DHS Wealth Index Factor score (C). All three versions of the DHS Wealth Index show positive associations with market-based assets, yet all three versions show null or negative associations with land and livestock ownership. Among households engaged primarily in agricultural production, the standard index may not be a clear measure of resource access.

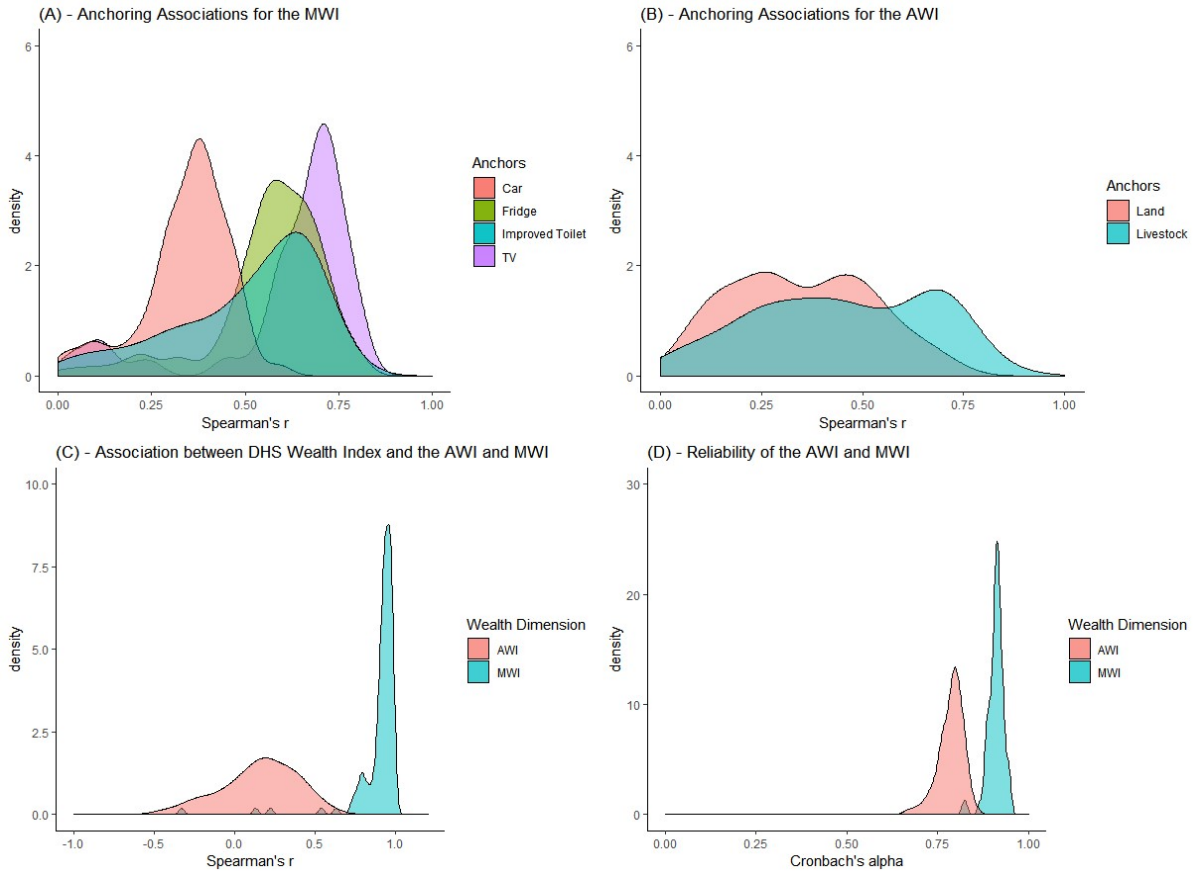

Figure 2. (A) The distribution of correlation coefficients between the dimension selected as the MWI and the market-based anchoring variables. (B) The distribution of correlation coefficients between the dimension selected as the AWI and the agricultural anchoring variables. (C) The distribution of correlation coefficients between the newly estimated wealth dimensions with the original DHS wealth index. (D) The distribution of the reliability estimates for the MWI and the AWI.

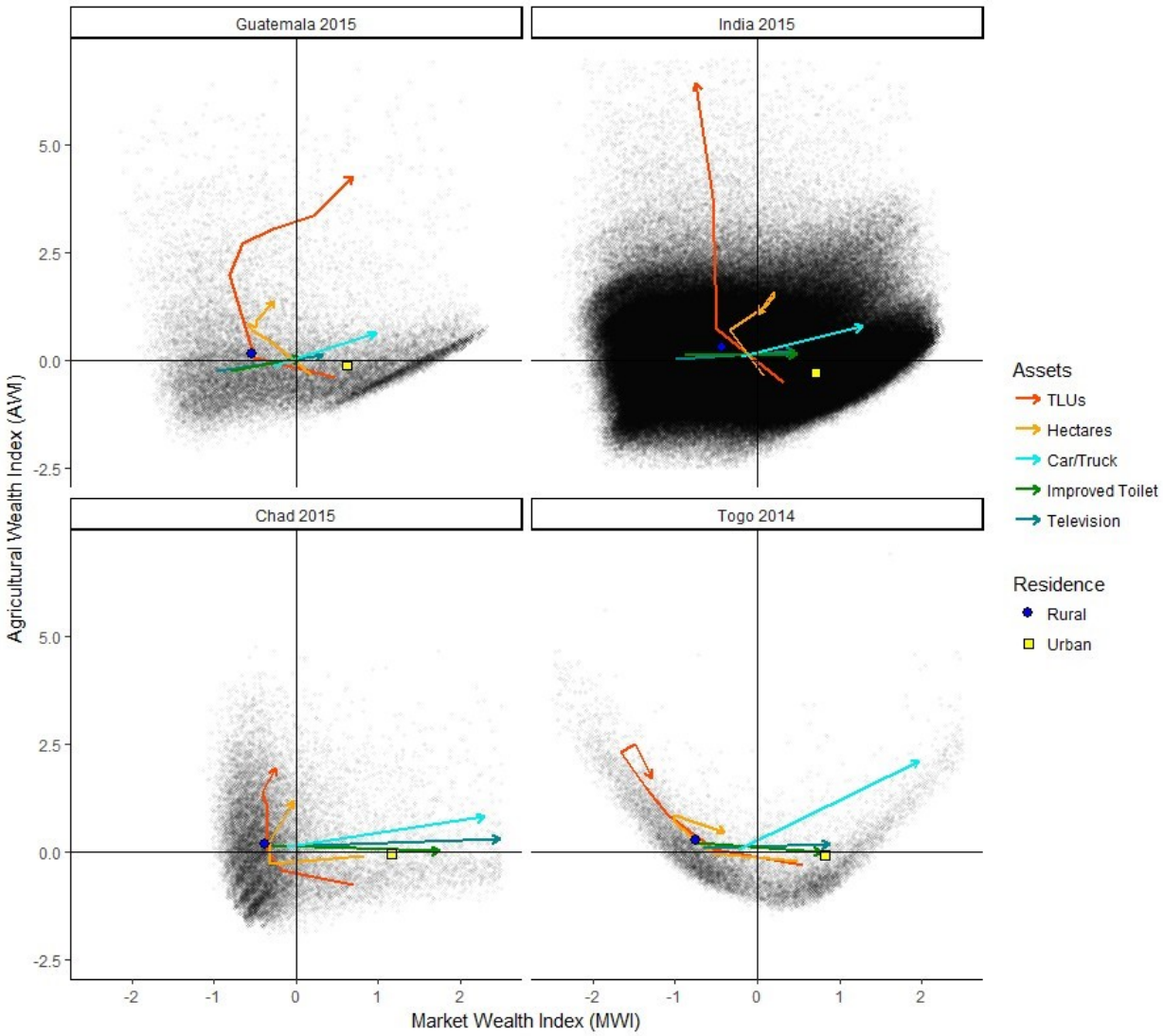

Figure 3. Examples of the “cloud” of households in 2-dimensional livelihood space. Arrows reflect the average position (centroid) of households with varying levels of asset ownership. For market-based assets – car, television, refrigerator, and improved toilet – the lines show the average movement between households without the asset to households that own it. These assets show movement primarily along the market wealth dimension (x-axis). For agricultural assets – TLUs and Land - the lines show movement across the full range of ordinal categories (0 to 16+ hectares and 0 to 16+ TLUs). Agricultural assets show movement primarily along the agricultural wealth dimension (y-axis). Mean values for urban and rural households show movement primarily along the market wealth dimension, rather than along the agricultural dimension.

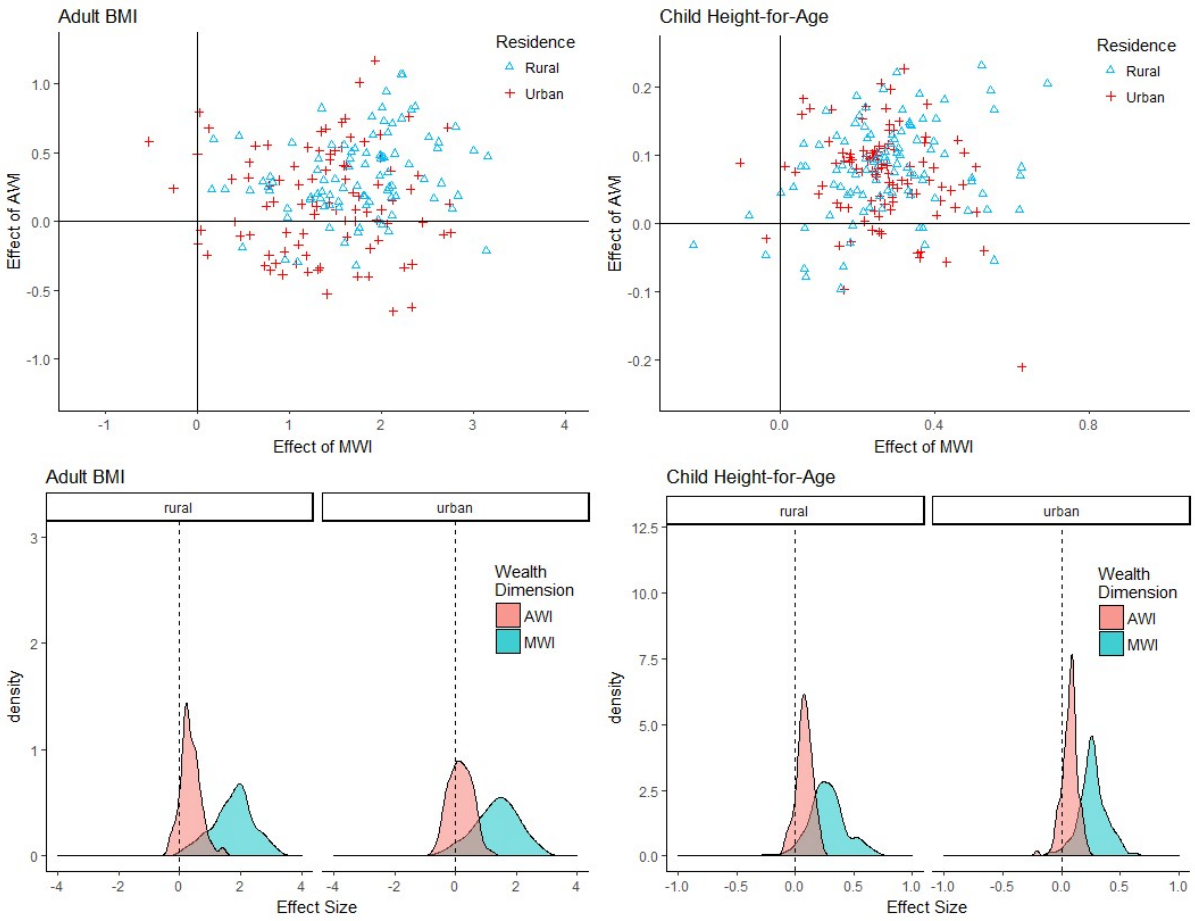

Figure 4. Estimated effects of AWI and MWI on adult BMI and child HAZ.

Table 1. Results of MLM Validation Models on Growth Outcomes				
	Adult BMI		Child Height-for-Age	
Predictors	Estimates	CI	Estimates	CI
(Intercept)	23.13 ***	22.50 – 23.76	-1.85 ***	-1.93 – -1.76
MWI	1.76 ***	1.60 – 1.91	0.28 ***	0.24 – 0.31
AWI	0.35 ***	0.27 – 0.43	0.08 ***	0.06 – 0.10
Primary	0.44 ***	0.39 – 0.48	0.12 ***	0.11 – 0.13
Secondary	0.56 ***	0.51 – 0.60	0.30 ***	0.28 – 0.31
Higher	0.05	-0.02 – 0.12	0.51 ***	0.49 – 0.53
Age	0.04 ***	0.03 – 0.04	0.01 ***	0.01 – 0.01
Age Spline at 24m	-	-	-0.04 ***	-0.05 – -0.04
Child Sex	-	-	0.11 ***	0.10 – 0.11
Urban	0.29 ***	0.16 – 0.43	0.03 *	0.00 – 0.06
MWI*Urban	-0.39 ***	-0.52 – -0.26	-0.01	-0.04 – 0.01
AWI*Urban	-0.20 ***	-0.30 – -0.10	-0.01	-0.03 – 0.01
Observations	354,323		712,048	
N-surveys	93		101	
N-countries	53		53	
* p<0.05 ** p<0.01 *** p<0.001				