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Different forms of household wealth are associated with opposing risks for HIV infection in East Africa

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ABSTRACT

The relationship between material wealth and HIV infection in sub-Saharan Africa has been the subject of considerable debate in part because many studies show that wealth is positively associated with infection. Others have critiqued such results, suggesting that the widely used indicators of wealth underlying these results fail to capture the diversity of livelihood portfolios in East Africa. Using population representative data from 35,799 households in Kenya, Ethiopia, and Tanzania, we estimate household wealth along two different dimensions, associated respectively with success in wage economies and agricultural economies. Regression models for men and women show consistent and opposing associations between type of wealth and HIV infection. Controlling for age, education, and urban dwelling, increasing achievement along the wage economy dimension is positively (often significantly) associated with HIV infection. In contrast, increasing achievement along the agricultural economy dimension is often negatively associated with HIV infection, and is never associated with increased HIV risk. Interestingly, variables to assess risky sexual behaviors do not mediate the relationship between either type of wealth and HIV infection. Our results suggest that future studies on the relationship between HIV and wealth need to take into account the different dimensions of household wealth found in East African countries. Our results also generate new, important questions about why and how different forms of wealth drive HIV infection.

1. Introduction

More than a decade ago, public health researchers began to identify a puzzling relationship between wealth and HIV in sub-Saharan Africa. First in Kenya and then in Tanzania, nationally-representative and cross-sectional surveys showed that men and women in wealthier households were at substantially greater risk of HIV infection than those from poorer households (Shelton, Cassell, & Adetunji, 2005). These findings were soon confirmed in a number of other countries, including Ghana, Malawi, Lesotho, Cameroon, and Burkina Faso (Mishra et al., 2007), and generated considerable debate about the social roots of HIV infection (Bingenheimer, 2007; Fox, 2012; Gillespie, Kadiyala, & Greener, 2007; Hargreaves, Davey, & White, 2012; Hargreaves, Davey, Fearon, Hensen, & Krishnaratne, 2015; Long & Deane, 2015; Lopman et al., 2007; Mishra et al., 2007; Parkhurst, 2010; Shelton et al., 2005). A positive relationship between HIV and wealth (or, HIV and education, Forston, 2008) potentially challenged emerging arguments that poverty-alleviation programs are a "key intervention in the fight against HIV" (Fenton, 2004). More broadly, they also provided a puzzling counter-example to the recurring finding in population health that indices of individual and household wealth robustly predict improved health across a range of measures (Wilkinson, Marmot, & ebrary Inc. 2003). Indeed, so robust is the positive association between access to resources and health that some social epidemiologists have labeled wealth and socioeconomic position "fundamental causes" in understanding the distribution of health across time and space (Link & Phelan, 1995).

Not surprisingly then, the paradoxical nature of the HIV-wealth relationship in sub-Saharan Africa generated considerable scholarship. For example, researchers have sought to describe more complex associations between household wealth and HIV, and have tried to explain varied findings on the relationship between HIV and wealth by testing the hypothesis that wealth might be positively associated with HIV infection early in an epidemic while later turning into a negative relationship as the epidemic unfolds over time—the so called "inverse equity hypothesis" (Hargreaves et al., 2012) (Victora, Vaughan, Barros, Silva, & Tomasi, 2000). However, these hypotheses met little empirical support in a recent

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study on the relationship between education and HIV infection among young people in East and Southern Africa (Hargreaves et al., 2015). Still others have focused on the interaction between household and national level poverty and wealth. For instance, Parkhurst (2010) suggested that wealth might be positively associated with infection probability in lower-income countries, whereas in higher-income countries the association may turn negative. Fox (2012) looked within countries and, also relying on DHS surveys, examined how the HIV-socioeconomic status association varies across wealthier and poorer regions, and, specifically, examined the role inequality may play in patterning the SES-HIV association. Her results from 170 regions in 16 countries show that "inequality trumps wealth" and that in wealthier regions/countries, poorer individuals are more likely to be infected, whereas in poorer regions/countries, wealthier individuals are more likely to be infected.

The results from each of these important studies rest critically on how household wealth is conceptualized and measured. It is important therefore to note that wealth estimates from the Demographic and Health Surveys (DHS) have dominated most work on the relationship between HIV and wealth with their large samples of households and individuals who have been tested for HIV. These studies have generally treated the measurement of wealth as unproblematic and have relied exclusively and uncritically on the DHS wealth index (Bingenheimer, 2007). The DHS wealth index is generated through a principal component analysis on household-level asset data, household construction attributes, and other variables such as source of drinking water. Consumer goods and modern housing construction load heavily on the first component, which ultimately becomes the wealth measure. On the other hand, the DHS wealth index down weights the importance of "traditional" forms of wealth, such as animal and land holdings, even though many African households construct a living through engagement in *either* a wage economy or an agricultural economy. This strongly suggests that this measure reflects a narrow conceptualization of wealth, specifically engagement in a wage economy. Based on this concern, Bingenheimer (2007) questioned the finding of many studies on the HIV-wealth relationship, specifically noting that the one-dimensional "wealth" scale used so frequently in HIV-wealth studies is "inconsistent with the complexities of contemporary African livelihoods" and, therefore, results linking "wealth" to HIV are potentially misleading. This leaves open the question of whether wealth matters for HIV or whether specific forms of wealth matter. This is the question we take up in this study.

Consistent with Bingenheimer's critique, anthropologists have spent considerable time unpacking and contextualizing the *meanings* of wealth and exploring the diverse ways in which people can craft livelihoods to accumulate wealth (Ferguson, 1992; Guyer, 1995; Hruschka, Hadley, & Hackman, 2017; Kaiser, Hruschka, & Hadley, 2017), finding, as Bingenheimer notes, that livelihoods can be complex. Anthropologists have explicated and debated the nature of wealth, assessing the extent to which wealth is a uni- or multidimensional construct, and determining what value is added to our understanding of health by incorporating locally appropriate wealth measures (Hadley & Wutich, 2009; Hruschka et al., 2017; Little, McPeak, Barrett, & Kristjanson, 2008; Tucker, Huff, Tsiazonera, Hajasoa, & Nagnisaha, 2011). Not surprisingly, these authors argue, whether implicitly or explicitly, that the diversity of livelihoods observed ethnographically might not map perfectly onto a single dimension of wealth. By drawing on ethnographic and experience-near knowledge, anthropologists have highlighted the diverse ways in which people make a living that, though successful, are orthogonal to capitalist modes of asset acquisition (BurnSilver, Madganz, Stotts, Beman, & Kofinas, 2016; Ferguson, 1992; Guyer, 1995; Little et al., 2008). The radically contextualizing approach of anthropology, contrasts with the use of single wealth metrics that are often applied cross-nationally. Notably, the Demographic and Health Surveys—multicountry, multiyear and nationally representative datasets—rely on a single wealth dimension based on asset ownership (Filmer & Pritchett, 2001; Rutstein, Johnson, Macro, & MEASURE, 2004). This measure and its single-dimensional variants may be among the most frequently used wealth indices in the health and social science literature (Hruschka, Gerkey, & Hadley, 2015; Rutstein & Stavestag, 2014; Smits & Steendijk, 2015). As such, as Bingenheimer hypothesized, it is possible that conclusions about the relationship between HIV and household wealth are marred by focusing on only one kind of wealth and, therefore, fail to consider the diverse pathways through which households accumulate material goods and status.

There is reason to believe that different forms of wealth will be differentially related to HIV risk. The growing literature on "sugar daddies" and transactional sex in sub-Saharan Africa repeatedly calls attention to cash and the material nature of the wealth exchanged. While reports highlight the exchange of sex for food (Weiser et al., 2007), especially among food insecure women, a more common theme, in both rural and urban settings, is the emphasis on the exchange of money, material goods, "fashionable goods", items linked with "conspicuous consumption" (Dunkle et al., 2007; Fielding-Miller, Dunkle, Cooper, Windle, & Hadley, 2016; Luke, Goldberg, Mberu, & Zulu, 2011; Maganja, Maman, Groves, & Mbwambo, 2007; Stoebenau, Heise, Wamoyi, & Bobrova, 2016; Wamoyi, Wight, Plummer, Mshana, & Ross, 2010) or, as Masvawure (2010) notes, exchanging sex to be seen as "high-status, successful modern subjects." Free lists of the items women hope to gain in sex transactions are overwhelmingly dominated by material goods (Fielding-Miller et al., 2016) and material exchange for sex has been linked with increased risk of HIV (Dunkle et al., 2004). These results suggest that wealth along a wage dimension may result in differential risk for HIV infection, perhaps mediated by increased numbers of partners, lack of condom use, or as suggested by Shelton et al, concurrent sexual partners (Shelton et al., 2005).

Until recently, a key barrier to assessing Bingenheimer's critique is the lack of diverse livelihood and wealth measures in the kinds of large, representative surveys that dominate discussions about the HIV-wealth relationship (Howe et al., 2012). This has changed in the last decade, as Demographic and Health Surveys have begun to ask standard questions about agricultural wealth, such as land and livestock ownership. Recently, researchers have applied standard data reduction techniques (such as Multiple Correspondence Analysis) to these new data to estimate and validate multiple dimensions of wealth (Greenacre and Jœ, 2006; Hruschka et al., 2017; Pagès, 2016). Applying these techniques to nationally representative survey data from Nepal, Bangladesh, Ethiopia, Kenya, Tanzania, and Guatemala, Hruschka et al. (2017) estimated a number of meaningful and reliable wealth dimensions. In each case, the MCA revealed at least two wealth dimensions in each country, and these generally mapped onto achievement: (1) in the wage economy and (2) the agricultural economy. Moreover, both achievement in the wage economy and agricultural economy showed strong *positive* associations with indicators of child and adult growth and household food insecurity, indicating that both dimensions of wealth positively contributed to physical wellbeing. In Kenya and Nepal a third reliable wealth dimension was also estimated which provided information about the kinds of agricultural livelihoods a household was pursuing (e.g. specializing in cattle ownership), but did not assess achievement per se. These results robustly suggest that multiple, orthogonal dimensions of wealth can contribute to our understanding of social inequality and health outcomes, and a one-dimensional wealth measure, especially one that down weights agricultural achievement, can miss important relationships between wealth and health outcomes.

In this paper, we apply this novel approach for estimating household wealth across multiple livelihood strategies to long-standing questions on the relationship between wealth and HIV (Hruschka et al., 2017). We argue that the debate over the association between HIV and wealth hinges on how wealth is measured and conceptualized, and we hypothesize that both perspectives on the wealth-HIV association might be correct if wealth is, in fact, multidimensional. We use multiple correspondence analysis to: (1) determine whether varying dimensions of wealth in Ethiopia, Kenya, and Tanzania are associated with HIV infection; (2) identify the direction of these associations; and, (3) explore which factors, if any, mediate the relationship between wealth type and HIV infection.

2. Methods

To explore the relationship between wealth and HIV, we use Demographic and Health Surveys from Tanzania (2011), Ethiopia (2011) and Kenya (2009). These were selected because all surveys: (1) come from some of the original countries where the HIV-wealth association was first identified; (2) come from countries where the authors have experience working; (3) include rich population-based data on housing structure, drinking water source, asset ownership, and animal and land holdings; (4) have data on individuals with known HIV status; and, (5) represent a range of variation in HIV prevalence (~1% to ~6%), per capita GDP ($341 to $967 per person, 2010 $US dollars), modes of economy (42% to 79% employed in agriculture), and proportion of the population living in an urban setting (17% to 29%). As outlined in Hruschka et al. (2017), we determined the number of relevant household-level wealth dimensions for each country individually. Specifically, we identified these dimensions from variables like household drinking water source, presence of a household electricity connection, household wall, roof and floor construction materials, type of toilet used (if any), type of cooking fuel used, and material asset ownership (i.e. bike, radio, mobile or landline telephone, carts, boats, trucks, scooters, and watches). We also scored households on their ownership of land, cattle, cows, sheep, goats, horses/donkeys and chickens (in Tanzania this also included pigs). Dichotomous variables were discretized and nominal variables were dichotomized. For example, if a household mentioned using a composting toilet we created a new variable, "composting toilet", which was dichotomized. Households in each country were assessed on approximately 130 unique dichotomous wealth variables (Hruschka et al., 2017).

To generate the wealth dimensions, we used R to conduct a weighted multiple correspondence analysis (MCA) on all available households and then merged those data with individual level data which included HIV status. The procedure estimates a "cloud of households" in a multidimensional space where distances between households are derived from differences in household assets. It then estimates a number of orthogonal dimensions running through that space that capture the largest amount of variation in asset ownership. The rationale for using MCA as well as a description of how it works and its relationship to principal component analysis are described in more detail in Hruschka et al. (2017). Following the procedure laid out in Hruschka et al. (2017), we applied MCA to the household-by-variable matrix separately for each country using the dichotomous measures mentioned above. We initially estimated four dimensions but only retained dimensions with acceptable internal reliabilities (Cronbach's alpha >0.70) and a clear interpretation; we opted to retain only the first two dimensions for each country. Households were then assigned a coordinate along each of the selected dimensions. To anchor our interpretation of the direction of each dimension (see also Hruschka et al., 2017), we explored how they varied across a suite of anchoring variables. Specifically, for each country we examined how both dimensions varied according to the household head's education level, rural or urban dwelling, whether the household had electricity, hectares of agricultural land and household ownership of cows and chickens. We also compared the DHS wealth index against wealth dimensions generated from the MCA. To facilitate analysis, we normalized dimension 1, dimension 2, and the DHS wealth index by the standard deviation of each.

To explore what factors might mediate the relationship between wealth-type and HIV we calculated the number of lifetime partners (coded as 0, 1–2, 3 or more) and the number of non-spousal partners in the last 12 months (coded as 0 or >0); from these we created dummy variables for: no partners ever, 1–2 lifetime partners and no extra spousal sexual relationships in the last 12 months, 1–2 lifetime partners with at least 1 extra spousal relationship, three or more lifetime partners and no extra spousal partners in last 12 months, and three or more lifetime partners with at least one spousal partner in the last 12 months. We included these with the aim of assessing whether their inclusion mediated the associations between the two wealth dimensions and HIV infection. We had hoped to include variables for concurrent sexual partners but the cells sizes were very small.

For our analytic strategy, we fit a logistic regression to estimate an individual's HIV status as a function of a household's score along each of two wealth dimensions. In addition to the wealth dimensions, we included age, gender, education level, [dummy coded as: none (reference), primary, secondary, higher] and urban residence as covariates. The wealth dimensions were initially broken into quintiles and entered into the models as dummy variables; analysis of the quintiles suggested that it was acceptable to model our wealth dimensions as linear continuous variables. We present models including both wealth dimensions, but also report models with each dimension included independently in the Supplementary materials. Those models do not qualitatively change the findings for wealth.

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We also tested an interaction between each wealth dimension and urban residence to assess whether different types of wealth differentially impacted HIV risk conditional upon place (see Supplementary materials). We present models with the interaction between urban residence and dimension 1 because the urban × dimension 1 interaction was significant in some of the models. As the urban × dimension 2 interaction was never significant, we exclude it from all models. Age was initially entered into the logistic models as a categorical variable; however, as results were substantially unchanged when modeled as a linear continuous variable, we present here models with age as a continuous variable. All analyses at the individual level were conducted using the HIV specific weights, and correlational and regression analyses were conducted accounting for complex sample design using the survey package for R.

3. Results

3.1. Identifying and characterizing dimensions of household wealth

Consistent with the original estimation of wealth in the surveys from these three countries (Hruschka et al., 2017), the MCA identified at least two reliable dimensions, with the first dimension highly correlated with the standard DHS wealth factor score ($r > 0.95$; SM Table S1) and the first two dimensions relatively orthogonal to each other (r < 0.10). Also consistent with previous estimations for the same surveys, the first dimension in each country was significantly correlated with access to electricity (r > 0.75), ownership of a TV (r > 0.50) and urban residence (r > 0.70). By contrast, the second dimension was significantly associated with ownership of chickens (r > 0.35) and cattle (r > 0.35) as well as ownership of land (r > 0.25). Moreover, the second agricultural wealth dimension was never strongly associated with urban residence (|r| < 0.10), nor with the standard DHS wealth factor score (r = 0.10, 0.18, 0.21). As in the original derivation of these measures, we interpret the first dimension as a measure of wealth in the wage economy and the second dimension as a measure of wealth in the agricultural economy.

3.2. Characterizing the relationship between HIV infection and dimensions of household wealth

In Ethiopia, 1.4% (1% male, 1.9% female) of the sample was HIV positive, while in Tanzania 3.9% of men and 6.2% of women were HIV positive, and in Kenya 6.3% of the sample was HIV positive (4.6% male, 8% female). We fit gender-specific logistic regression models with controls for age, education and place of dwelling to each country's data and our estimates of wage-based (dimension 1) and agricultural-based wealth (dimension 2).

Results of logistic regressions predicting HIV status for Ethiopia, Tanzania and Kenya are shown in Tables 1–3, while Fig. 1 (for urban dwellers) and Fig. 2 (for rural dwellers) depict the predicted probability of HIV infection by the wage economy and agricultural wealth dimensions controlling for individual age (what?) and education. Consistent with previous studies that used the standard DHS wealth index, accumulation along the wage economy dimension (i.e., dimension 1) was significantly associated with increased HIV among men in all three countries—Tanzania (beta: 0.36 95%CI 0.04, 0.68), Ethiopia (beta: 1.18, 95%CI 0.86, 1.50), and Kenya (beta: 0.46, 95% CI 0.11, 0.82). The interaction between wage economy wealth and urban residence was significant for Ethiopian men (−0.81 95%CI −1,23, −0.40) and Kenyan men (−0.66, 95%CI −1.21, −0.07) indicating that the association between the wage economy dimension (dimension 1) and HIV was greater in rural areas.

We find a similar positive and significant association between wage economy wealth and HIV for women in Tanzania (beta 0.40, 95%CI 0.23, 0.58) and Ethiopia (beta 1.14 95%CI 0.58, 1.71), while the association was positive but not significant in Kenya (beta: 0.16 95%CI −0.16, 0.47). The interaction between wage economy wealth and urban residence was significant for Tanzanian women (−0.46 95%CI −0,73, −0.19) and Ethiopian women (−0.83, 95%CI −141, −0.25) indicating that the association between dimension 1 and HIV is greater in rural areas.

By contrast, accumulation along the agricultural dimension was consistently negatively associated with reduced HIV risk for both men and women. This result was statistically significant for men in Tanzania (beta: −0.29, −0.48, −0.10), marginally significant for men in Ethiopia (beta −0.30, 95%CI −0.63, 0.03), and negative but not significant in Kenya (beta: −0.06, −0.35, 0.23). It was statistically significant for women in all countries: Tanzania (beta: −0.25, 95%CI −0.38, −0.12), Kenya (beta: −0.41 95%CI −0.65, −0.18), and Ethiopia (beta −0.35, 95%CI −0.58, −0.12).

3.3. Do sexual behaviors mediate this relationship?

To assess whether variables related to sexual behaviors mediated the relationship between different types of wealth and HIV infection, we added sexual behavior variables to the models and explored changes in the magnitude of the wealth variable coefficients. As shown in Tables 1–3, variables measuring sexual behaviors were often positive predictors of HIV infection. For women in all three countries, having reported any sexual partners was a positive predictor of HIV status, with the largest increases among those who had reported >2 lifetime partners. The results were less consistent for men, with no significant effect of reported sexual partners in Tanzania, a significant increase for those reporting >2 lifetime partners in Ethiopia and Kenya, and a significant increase in Ethiopia for those reporting 1–2 lifetime partners and no extra-spousal sexual partners in the last 12 months. Despite these significant associations, adding sexual behaviors to the models did not consistently or substantially impact the relationship between the wealth dimensions and HIV infection.

4. Discussion

The relationship between wealth and HIV has excited much academic and policy interest. In this study we sought to assess the hypothesis that wealth associated with different livelihoods—that is, multiple material wealths—may be differentially associated with HIV infection. Our results strongly support this notion.

Table 1
Logistic regression predicting HIV risk in Ethiopia.

	Women		Men	
	Model 1	Model 2	Model 1	Model 2
Urban dweller, yes	1.18*** (0.66, 1.69)	1.28*** (0.76, 1.80)	1.20*** (0.46, 1.94)	1.16*** (0.49, 1.84)
Age, years	0.07*** (0.05, 0.09)	0.03*** (0.01, 0.05)	0.05*** (0.04, 0.07)	0.01 (−0.01, 0.03)
Education				
Primary school	0.46 (−0.13, 1.05)	0.53* (−0.04, 1.10)	0.08 (−0.76, 0.91)	0.04 (−0.75, 0.84)
Secondary school	0.40 (−0.80, 1.61)	0.66 (−0.57, 1.88)	0.10 (−0.66, 0.86)	0.16 (−0.57, 0.90)
More than secondary	−1.02** (−1.98, −0.06)	−0.92* (−1.90, 0.06)	−0.91** (−1.80, −0.02)	−1.01** (−1.94, −0.08)
Wealth Dimension				
Wage	1.14*** (0.58, 1.71)	1.08*** (0.57, 1.59)	1.18*** (0.86, 1.50)	1.12*** (0.80, 1.43)
Agricultural	−0.35*** (−0.58, −0.12)	−0.22* (−0.44, 0.01)	−0.30* (−0.63, 0.03)	−0.22 (−0.54, 0.10)
Sexual Partners (LT = Lifetime partners, yes/no refers to extra spousal relationship)				
1–2 LT, no 12 mo		2.12*** (1.31, 2.92)		2.83*** (1.63, 4.02)
1–2 LT, yes 12 mo		2.49*** (1.44, 3.54)		−0.06 (−1.82, 1.71)
>2 LT, no 12 mo		3.17*** (2.23, 4.10)		3.86*** (2.68, 5.05)
>2 LT, yes 12 mo		3.44*** (2.37, 4.52)		3.92*** (2.61, 5.22)
Wage × Urban	−0.83*** (−1.41, −0.25)	−0.81*** (−1.34, −0.29)	−0.81*** (−1.23, −0.40)	−0.88*** (−1.28, −0.48)
Constant	−6.56*** (−7.61, −5.50)	−7.63*** (−8.91, −6.34)	−6.81*** (−7.75, −5.88)	−8.23*** (−9.58, −6.89)

* p < 0.1.
** p < 0.05.
*** p < 0.01.

Table 2
Logistic regression predicting HIV risk in Kenya.

	Women		Men	
	Model 1	Model 2	Model 1	Model 2
Urban dweller, yes	0.31 (−0.34, 0.95)	0.21 (−0.45, 0.88)	0.03 (−0.61, 0.67)	−0.01 (−0.65, 0.63)
Age, years	0.04*** (0.02, 0.05)	0.01 (−0.01, 0.04)	0.05*** (0.03, 0.06)	0.03** (0.004, 0.05)
Education				
Primary school	0.66* (−0.00, 1.31)	0.47 (−0.21, 1.15)	0.65 (−0.66, 1.97)	0.45 (−0.96, 1.85)
Secondary school	0.36 (−0.39, 1.12)	0.28 (−0.46, 1.03)	0.02 (−1.37, 1.42)	−0.10 (−1.58, 1.38)
More than secondary	0.63 (−0.28, 1.55)	0.58 (−0.39, 1.54)	0.18 (−1.35, 1.71)	−0.003 (−1.63, 1.63)
Wealth Dimension				
Wage	0.16 (−0.16, 0.47)	0.10 (−0.20, 0.41)	0.46*** (0.11, 0.82)	0.39** (0.03, 0.75)
Agricultural	−0.41*** (−0.65, −0.18)	−0.36*** (−0.59, −0.13)	−0.06 (−0.35, 0.23)	−0.03 (−0.33, 0.26)
Sexual Partners (LT = Lifetime partners, yes/no refers to extra spousal relationship)				
1–2 LT, no 12 mo		1.54*** (0.63, 2.44)		1.17 (−0.56, 2.90)
1–2 LT, yes 12 mo		1.39** (0.20, 2.59)		−0.21 (−2.75, 2.32)
>2 LT, no 12 mo		2.39*** (1.39, 3.39)		2.25** (0.53, 3.96)
>2 LT, yes 12 mo		2.99*** (1.97, 4.01)		2.26*** (0.59, 3.94)
Wage × Urban	−0.15 (−0.67, 0.37)	−0.08 (−0.60, 0.44)	−0.66** (−1.24, −0.07)	−0.63** (−1.22, −0.05)
Constant	−4.16*** (−5.06, −3.27)	−4.98*** (−6.20, −3.77)	−4.76*** (−6.20, −3.32)	−5.78*** (−7.88, −3.69)

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 3
Logistic regression predicting HIV risk in Tanzania.

	Women		Men	
	Model 1	Model 2	Model 1	Model 2
Urban dweller, yes	0.56*** (0.23, 0.90)	0.48*** (0.14, 0.83)	0.09 (−0.51, 0.70)	0.07 (−0.54, 0.68)
Age, years	0.05*** (0.04, 0.06)	0.04*** (0.03, 0.05)	0.06*** (0.04, 0.07)	0.05*** (0.03, 0.07)
Education				
Primary school	0.08 (−0.26, 0.42)	0.12 (−0.22, 0.45)	−0.06 (−0.54, 0.43)	−0.06 (−0.56, 0.44)
Secondary school	−0.10 (−0.55, 0.35)	0.06 (−0.38, 0.50)	−0.99*** (−1.68, −0.29)	−0.91** (−1.61, −0.22)
More than secondary	−0.70 (−2.89, 1.48)	−0.56 (−2.66, 1.55)	−0.03 (−1.68, 1.62)	−0.03 (−1.69, 1.62)
Wealth Dimension				
Wage	0.40*** (0.23, 0.58)	0.38*** (0.20, 0.56)	0.36** (0.04, 0.68)	0.35** (0.03, 0.66)
Agricultural	−0.25*** (−0.38, −0.12)	−0.17*** (−0.30, −0.04)	−0.29*** (−0.48, −0.10)	−0.29*** (−0.47, −0.10)
Sexual Partners (LT = Lifetime partners, yes/no refers to extra spousal relationship)				
1–2 LT, no 12 mo		1.01*** (0.35, 1.67)		0.17 (−0.89, 1.23)
1–2 LT, yes 12 mo		1.16*** (0.33, 1.99)		0.25 (−0.91, 1.40)
>2 LT, no 12 mo		1.37*** (0.68, 2.05)		0.57 (−0.43, 1.56)
>2 LT, yes 12 mo		2.07*** (1.37, 2.77)		0.71 (−0.24, 1.66)
Dimension 1 × Urban	−0.46*** (−0.73, −0.19)	−0.47*** (−0.74, −0.19)	−0.03 (−0.54, 0.48)	−0.03 (−0.53, 0.48)
Constant	−4.44*** (−4.89, −3.99)	−5.35*** (−6.09, −4.61)	−4.97*** (−5.63, −4.32)	−5.20*** (−6.22, −4.19)

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Specifically, we find a broad pattern whereby accumulation of wealth along a wage economy dimension is associated with increased likelihood of infection, a finding that replicates previous studies using the standard DHS wealth index. Meanwhile, accumulation of wealth along an agricultural spectrum is associated with lower likelihoods of infection (and nearly always significantly so). Our results therefore imply that wealth can be both positively associated with HIV infection and negatively associated with HIV infection depending on the livelihood examined. This result is even more interesting given our previous results suggesting that achievement along both dimensions is positively associated with other aspects of human wellbeing, such as physical growth and food security (Hruschka et al., 2017).

An outstanding question is how or why wealth in these different livelihood domains acts to protect or place people at risk. One set of hypotheses might be that different forms of wealth act through sexual behaviors that place people at differential risk. Specifically, wealth in the wage economy might be differentially associated with number of partners, non-stable or non-primary partners, and condom use. To explore this possibility, we included relevant sexual risk variables in our regressions. While these variables were often significant predictors of HIV infection, they did not appear to mediate the relationship between the wealth dimensions and HIV status. Like others who have proposed sexual behaviors as a possible mediator between wealth and HIV (Shelton et al., 2005) we are left without a clear understanding of how these different forms of material wealth impacts HIV risk or, more specifically, why achievement on differing dimensions of wealth differentially impacts HIV infection. It is possible that differential response bias to questions about sexual behavior among people that fall along dimension 1 and 2 may have attenuated any potential mediation by these variables. For instance, Lindstrom et al. (2010), when comparing a standard face to face interview with a method that increased respondent confidentiality, found that young people's response in urban settings were unaffected by response mode, while young people in rural settings were much more likely to give lower estimates of sexual behaviors in a

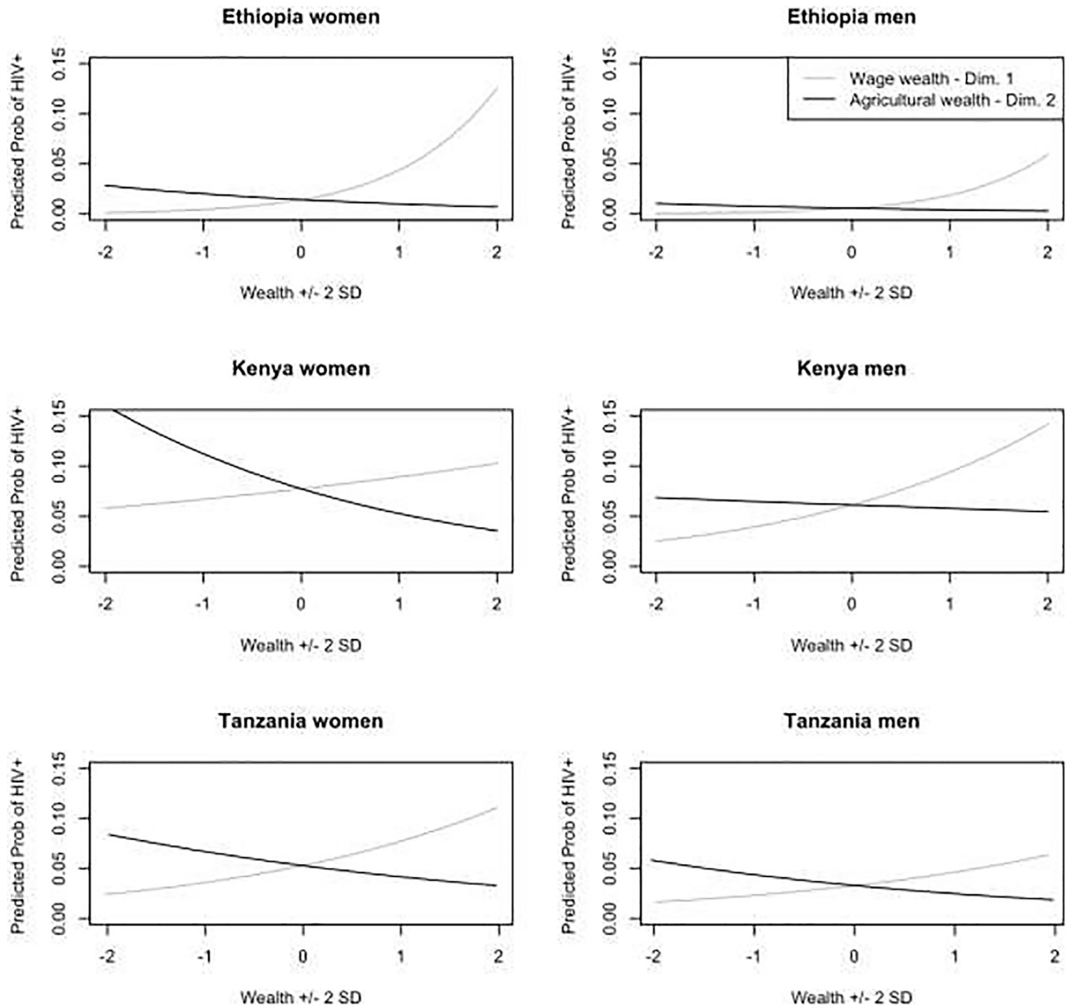

Fig. 1. Predicted probabilities of HIV infection for men and women in three East African countries. Predicted values are for *rural* dwellers with primary education and the average age for each sex in the country.

face to face interview. It is therefore possible that differential response bias clouds any potential mediation by sexual behaviors. It is also possible the individuals who are high (or low) on either wealth dimension are embedded within sexual networks that have different characteristics, including a different prevalence of HIV infection.

Another possible explanation for the negative association between agricultural wealth and HIV status is that it is an artifact of using an MCA to measure wealth, whereby urban households high in wage economy wealth but low on the agricultural dimension drive the relationship. However, there are two reasons that this is unlikely. First, there is no correlation between the agricultural wealth dimension and either: (1) the wage economy dimension or (2) urban residence. Thus, being a wealthy urban household does not mean that one will have a lower average value on agricultural wealth. If the proposal is correct, we would also expect the effect of agricultural wealth to be strongest in urban areas. Contrary to this expectation, we find that there are no significant interactions of urban residence by the agricultural wealth dimension.

Our results also suggest that hypotheses based upon the temporal aspects of within country HIV epidemics must be sensitive to the multiple dimensions of wealth as well as how these may change with time. Attention to the temporal aspect also highlights the fact that most studies of HIV and wealth thus far have been cross-sectional, and that longitudinal studies are critical for testing many hypotheses that focus on dynamic variables, like shifts in HIV prevalence. For example, the reverse equity hypothesis assumes that the shift in the burden of HIV epidemics moves from the wealthy to the poor over time. In the fullest test of this idea to date, Hargreaves et al. (2015) report finding little evidence of the dynamics they predicted and conclude that exploring the heterogeneity of HIV in Africa "will need to account for time-trends and inter-country differences". Lopman and colleagues however find some support for a shift in Zimbabwe (Lopman et al., 2007). However, this was during a time of rapid economic deterioration. More recently, Iorio and Santaeulalia-Llopis (2016) explore the temporal dynamics of the education-HIV association in 39 countries, finding that as an epidemic progresses the relationship between education and HIV infection shifts from positive to zero and back to positive. These results, when coupled with ours, suggest that it may be similarly fruitful to explore shifts in wealth and livelihoods over time. Given the opposing effects of wealth type on HIV risk that we observe in Kenya, Ethiopia, and Tanzania, if the underlying nature of wealth or the relative distribution of wage and agricultural wealth is also shifting over time or varies across countries, then this may account for the observed shifts in HIV risk over time and space. Shifts in the distribution of the HIV burden over time may simply reflect that poorer households are increasing, if slightly, their achievement in the wage economy while perhaps decreasing their achievement in the agricultural

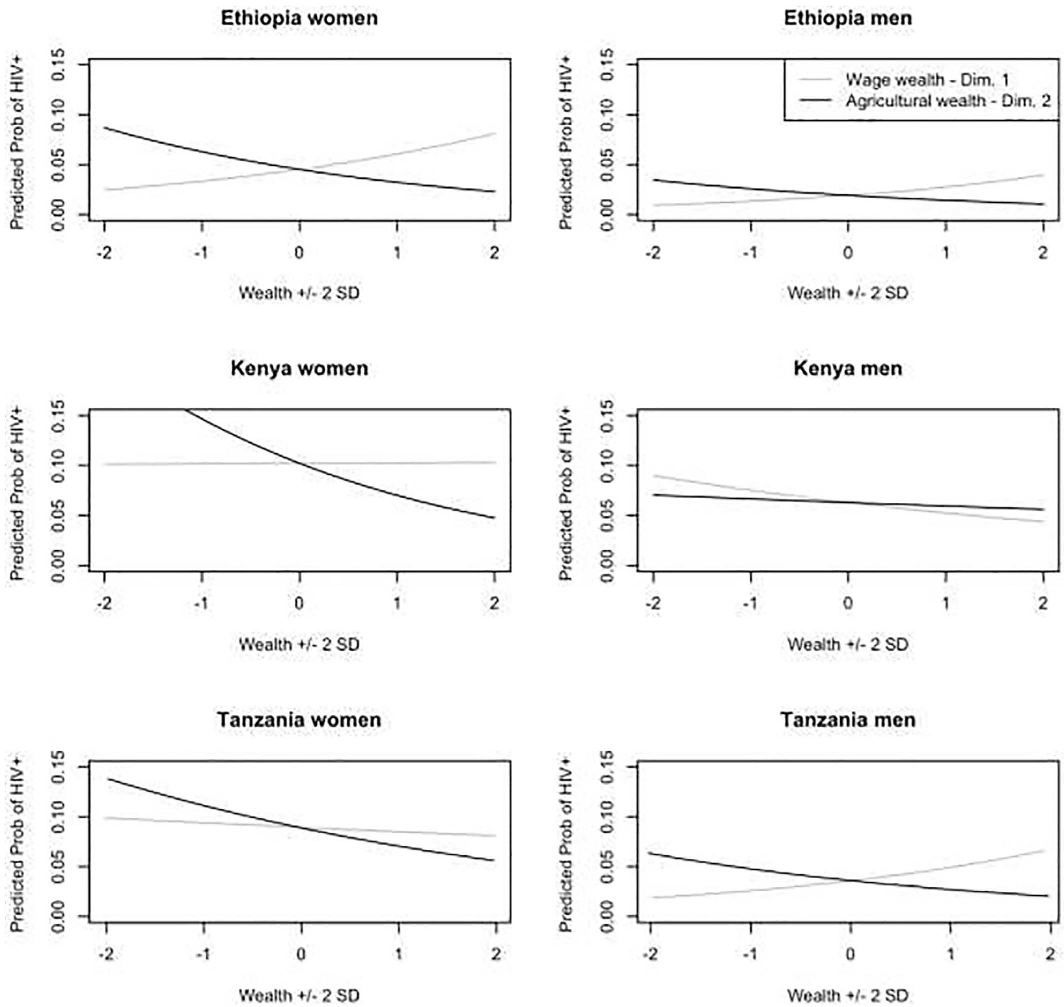

Fig. 2. Predicted probabilities of HIV infection for men and women in three East African countries. Predicted values are for *urban* dwellers with primary education and the average age for each sex in the country.

economy (Brockington et al., 2017; Harttgen, Klasen, & Vollmer, 2013). An additional finding from our study that deserves further investigation is that the strength of the association between different wealth types can vary by place. For example, the positive association between wage economy wealth is significantly stronger in rural areas in four of the six samples. We hope to explore this intriguing finding in future work with data from more countries.

Our results here build on our previous work, which establishes the reliability, interpretability and construct validity of using MCA to discover various dimensions of household wealth (Hruschka et al., 2017). Our results here show how using these tools to interrogate large datasets provides new insights into the social determinants of health in Africa, and especially how the nature of the social determinants of health vary by livelihood strategy. Our results strongly suggest that wealth does indeed impact HIV and, depending on which type of wealth we are talking about, can do so in fundamentally opposing fashions.

Conflict of interest

None declared.

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References

Bingenheimer, J. B. (2007). Wealth, wealth indices and HIV risk in East Africa. *International Perspectives on Sexual and Reproductive Health, 33*(2), 83–84.

Brockington, D, Loiske, V.-M., Mnzava, M., & Noe, C. (2017). Economic growth and rural assets and prosperity: Exploring the implications of a twenty year record from Tanzania. unpublished manuscript.

BurnSilver, S., Madganz, J., Stotts, R., Beman, M., & Kofinas, G. (2016). Are mixed economies persistent or transitional? Evidence using social networks from Arctic Alaska. *American Anthropologist, 118*(1), 121–129.

Dunkle, K. L., Jewkes, R., Nduna, M., Jama, N., Levin, J., Sikweyiya, Y., & Koss, M. P. (2007). Transactional sex with casual and main partners among young South African men in the rural Eastern Cape: Prevalence, predictors, and associations with gender-based violence. *Social Science and Medicine, 65*(6), 1235–1248.

Dunkle, K. L., Jewkes, R. K., Brown, H. C., Gray, G. E., McIntryre, J. A., & Harlow, S. D. (2004). Transactional sex among women in Soweto, South Africa: Prevalence, risk factors and association with HIV infection. *Social Science and Medicine, 59*(8), 1581–1592.

Fenton, L. (2004). Preventing HIV/AIDS through poverty reduction: The only sustainable solution? *Lancet, 364*(9440), 1186–1187.

Ferguson, J. (1992). The cultural topography of wealth – Commodity paths and the structure of property in Rural Lesotho. *American Anthropologist, 94*(1), 55–73.

Fielding-Miller, R., Dunkle, K. L., Cooper, H. L., Windle, M., & Hadley, C. (2016). Cultural consensus modeling to measure transactional sex in Swaziland: Scale building and validation. *Social Science and Medicine, 148*, 25–33.

Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data–or tears: An application to educational enrollments in states of India. *Demography, 38*(1), 115–132.

Forston, J. G. (2008). The gradient in sub-Saharan Africa: Socioeconomic status and HIV/AIDS. *Demography, 45*(2), 303–322.
Fox, A. M. (2012). The HIV-poverty thesis re-examined: Poverty, wealth or inequality as a social determinant of HIV infection in sub-Saharan Africa? *Journal of Biosocial Science, 44*(4), 459–480.
Gillespie, S., Kadiyala, S., & Greener, R. (2007). Is poverty or wealth driving HIV transmission? *AIDS, 21*(Suppl 7), S5–S16.
Greenacre, M. J., & Jœ, Blasius (2006). *Multiple correspondence analysis and related methods. Statistics in the social and behavioral sciences series* (p. 581). Boca Raton: Chapman & Hall/CRC, p. xx.
Guyer, J. I. (1995). Wealth in people, wealth in things – Introduction. *Journal of African History, 36*(1), 83–90.
Hadley, C., & Wutich, A. (2009). Experience-based measures of food and water security: Biocultural approaches to grounded measures of insecurity. *Human Organ, 68*(4), 451–460.
Hargreaves, J., Davey, C., & White, R. (2012). Does the 'inverse equity hypothesis' explain how both poverty and wealth can be associated with HIV prevalence in sub-Saharan Africa? *Journal of the International AIDS Society, 15*, 175–176.
Hargreaves, J. R., Davey, C., Fearon, E., Hensen, B., & Krishnaratne, S. (2015). Trends in socioeconomic inequalities in HIV prevalence among young people in seven countries in Eastern and Southern Africa. *PLoS One, 10*(3).
Harttgen, K., Klasen, S., & Vollmer, S. (2013). An African growth miracle? Or: What do asset indices tell us about trends in economic performance? *Review of Income and Wealth, 59*, S37–S61.
Howe, L. D., Galobardes, B., Matijasevich, A., Gordon, D., Johnston, D., Onwujekwe, O., ... Hargreaves, J. R. (2012). Measuring socio-economic position for epidemiological studies in low- and middle-income countries: A methods of measurement in epidemiology paper. *International Journal of Epidemiology, 41*(3), 871–886.
Hruschka, D. J., Gerkey, D., & Hadley, C. (2015). Estimating the absolute wealth of households. *Bulletin of the World Health Organization, 93*, 483–490.
Hruschka, D. J., Hadley, C., & Hackman, J. (2017). Material wealth in 3D: Mapping multiple paths to prosperity in low- and middle-income countries. *PLoS One, 12*(9).
Iorio, D., & Santaeulalia-Llopis, R. (2016). Education, HIV status and risky sexual behavior: How much does the stage of the HIV epidemic matter? EUI Working Papers 2016/09.
Kaiser, B. N., Hruschka, D., & Hadley, C. (2017). Measuring material wealth in low-income settings: A conceptual and how-to guide. *American Journal of Human Biology, 29*(4).
Lindstrom, D. P., Belachew, T., Hadley, C., Hattori, M. K., Hogan, D., & Tessema, F. (2010). Nonmarital sex and condom knowledge among Ethiopian young people: Improved estimates using a nonverbal response card. *Studies in Family Planning, 41*(4), 251–262.
Link, B. G., & Phelan, J. (1995). Social conditions as fundamental causes of disease. *Journal of Health and Social Behavior*. Spec No:80-94.
Little, P. D., McPeak, J., Barrett, C. B., & Kristjanson, P. (2008). Challenging orthodoxies: Understanding poverty in pastoral areas of East Africa. *Development and Change, 39*(4), 587–611.
Long, D. Y., & Deane, K. (2015). Wealthy and healthy? New evidence on the relationship between wealth and HIV vulnerability in Tanzania. *Review of African Political Economy, 42*(145), 376–393.
Lopman, B., Lewis, J., Nyamukapa, C., Mushati, P., Chandiwana, S., & Gregson, S. (2007). HIV incidence and poverty in Manicaland, Zimbabwe: Is HIV becoming a disease of the poor? *AIDS, 21*(Suppl 7), S57–66.
Luke, N., Goldberg, R. E., Mberu, B. U., & Zulu, E. M. (2011). Social exchange and sexual behavior in young women's premarital relationships in Kenya. *Journal of Marriage and Family, 73*(5), 1048–1064.
Maganja, R. K., Maman, S., Groves, A., & Mbwambo, J. K. (2007). Skinning the goat and pulling the load: Transactional sex among youth in Dar es Salaam, Tanzania. *AIDS Care, 19*(8), 974–981.
Masvawure, T. (2010). 'I just need to be flashy on campus': Female students and transactional sex at a university in Zimbabwe. *Culture, Health & Sexuality, 12*(8), 857–870.
Mishra, V., Assche, S. R. V., Greener, R., Vaessen, M., Hong, R., Ghys, P. D., ... Rutstein, S. (2007). HIV infection does not disproportionately affect the poorer in sub-Saharan Africa. *AIDS, 21*, S17–S28.
Pagès, J. (2016). *Multiple factor analysis by example using R*. CRC Press.
Parkhurst, J. O. (2010). Understanding the correlations between wealth, poverty and human immunodeficiency virus infection in African countries. *Bulletin of the World Health Organisation, 88*(7), 519–526.
Rutstein S, Johnson K, & ORC Macro MEASURE. ORC Macro MD. (2004). The DHS wealth index.
Rutstein, S. O., & Staveteig, S. (2015). *Making the demographic and health surveys wealth index comparable*.
Shelton, J. D., Cassell, M. M., & Adetunji, J. (2005). Is poverty or wealth at the root of HIV? *Lancet, 366*(9491), 1057–1058.
Smits, J., & Steendijk, R. (2015). The international wealth index (IWI). *Social Indicators Research, 122*(1), 65–85.
Stoebenau, K., Heise, L., Wamoyi, J., & Bobrova, N. (2016). Revisiting the understanding of "transactional sex" in sub-Saharan Africa: A review and synthesis of the literature. *Social Science and Medicine, 168*, 186–197.
Tucker, B., Huff, A., Tsiazonera, Tombo J, Hajasoa, P., & Nagnisaha, C. (2011). When the wealthy are poor: poverty explanations and local perspectives in Southwestern Madagascar. *American Anthropologist, 113*(2), 291–305.
Victora, C. G., Vaughan, J. P., Barros, F. C., Silva, A. C., & Tomasi, E. (2000). Explaining trends in inequities: Evidence from Brazilian child health studies. *Lancet, 356*(9235), 1093–1098.
Wamoyi, J., Wight, D., Plummer, M., Mshana, G. H., & Ross, D. (2010). Transactional sex amongst young people in rural northern Tanzania: An ethnography of young women's motivations and negotiation. *Reproductive Health, 7*, 2.
Weiser, S. D., Leiter, K., Bangsberg, D. R., Butler, L. M., Percy-de Korte, F., Hlanze, Z., ... Heisler, M. (2007). Food insufficiency is associated with high-risk sexual behavior among women in Botswana and Swaziland. *PLoS Medicine, 4*(10), 1589–1597. discussion 1598.
Wilkinson, R. G., Marmot, M. G., & ebrary Inc. (2003). *Social determinants of health the solid facts* (p. 33). Copenhagen: World Health Organization, Regional Office for Europe.