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# Causal effects of HIV on employment status in low-income settings



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## ABSTRACT

This paper estimates the causal impact of being HIV positive on individual employment status using a recursive bivariate probit with male circumcision as the instrument to overcome the endogeneity arising from simultaneity bias. The results show that being HIV positive reduces the probability of being employed by 5 percentage points among males in Uganda. The effect is greater for individuals employed in manual labor than non-manual labor. When limiting the sample to mainly individuals employed in subsistence agriculture, we find a 4 percentage point reduction in the likelihood of employment, suggesting that the effect occurs primarily through reductions in labor supply as opposed to demand. This is supported by additional analysis using univariate probit regressions to assess the association between different levels of HIV illness (as measured by CD4 cell count) and the likelihood of employment. The magnitude of the association increases as CD4 cell count decreases. Having a CD4 cell count of 200 per mm<sup>3</sup> or below is associated with a 9 percentage point reduction in employment compared to individuals with CD4 cell counts above 200 per mm<sup>3</sup>.

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## 1. Introduction

HIV/AIDS is a leading cause morbidity and mortality in sub-Saharan Africa, where 25 million people are living with the disease. Antiretroviral therapy (ART) has been shown to reduce mortality among those infected, and global health policies such as the UNAIDS “3 by 5” campaign (to provide ART to 3 million people living with HIV/AIDS in low- and middle-income countries, LMICs, by 2005) have promoted the provision of ART.<sup>1</sup> As a result of action around initiatives like this, AIDS related deaths fell by 39% in sub-Saharan Africa between 2005 and 2013 (UNAIDS, 2014). In 2015, the World Health Organization (WHO) adopted a “treat all” approach, recommending that countries treat all HIV-infected individuals with ART as soon after diagnosis as possible. Despite this, the proportion of people living with HIV in Sub-Saharan Africa on ART remains approximately 50% (World Bank, 2017a).

In addition to the reduction in mortality that results from increases in ART uptake, there are also improved employment outcomes in terms of labor market participation and productivity (Larson et al., 2008; Thirumurthy et al., 2008, 2011; Habyarimana et al., 2010; Rosen et al., 2010). However, due to the cost of ART, low

budgets for health care and human resources constraints, the scale up of ART coverage remains slow (Kinsman, 2010). Decisions around how to allocate health system resources, e.g., to ART scale up or to other interventions for HIV/AIDS (e.g., prevention or cure, should one become available) or other illnesses are generally made on the basis of costs and health effects, but health is not the only thing that is socially valuable. Recognising that decision makers are often interested in a broader range of outcomes, the Second Panel on Cost-Effectiveness in Health and Medicine has recommended quantifying the impact across different sectors including the labor market (Sanders et al., 2016). It is therefore important to understand the causal effect of HIV on employment.

Estimating a causal effect of HIV/AIDS on employment is challenging, and requires careful consideration of three interrelated issues. The first concern is justification bias where respondents seek to justify their reduced labor supply via ill health or because government or insurance programs involve financial incentives to report being unhealthy (Currie and Madrian, 1999; Bazzoli, 1985). The second is simultaneity bias, which arises when the outcome and treatment variable of interest affect the other concurrently. The third concern is omitted variable bias, where health and employment are jointly determined by an unobserved variable (Lindeboom, 2006). Consequently health status should be treated as an endogenous variable in labor supply equations.

The sectoral pattern of employment growth and productivity growth have been shown to be important for poverty reduction

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<sup>1</sup> ART has also been shown to lead to greater private preventative behavior in Zambia (Wilson, 2016).

(Gutierrez et al., 2007), and we explore this by evaluating the effect of HIV on employment among manual versus non-manual laborers. As the labor demand side should not be a factor for those who practice subsistence agriculture, we estimate the effect on that subsample in an effort to identify the labor supply side impact. Another issue concerns the disease pathway, in particular, whether the severity of disease has an impact on employment. If the effect occurs largely on the supply side, we would expect the effect size to be greater as disease becomes more severe. Information on this is important for the optimal prioritization of HIV policy and care, and can possibly be captured through analysis of different observed levels of CD4 count. CD4 cell count is affected by both duration of HIV-infection and treatment with ART (Mermin et al., 2004; Girardi et al., 2001; Samet et al., 2001). CD4 cells are white blood cells that play an important role in fighting infections. HIV-negative individuals typically have CD4 cell counts of above 500 cells/mm<sup>3</sup> (Hughson, 2017). HIV uses CD4 cells to replicate, resulting in the destruction of these cells over time following infection. In the absence of ART, CD4 cell count declines over time as the virus replicates subsequently leading to AIDS over the course of 6–10 years. As the illness progresses flu-like symptoms may be present, as well as diarrhea, fatigue and balance issues among others that may affect an individual's ability to maintain employment.

The effect that HIV has on individual employment, as well as the labor market more broadly, has been the subject of previous investigation in both low- and middle-income countries. At the microeconomic level, Fox et al. (2004) assess the productivity of HIV-positive workers on a tea estate in Kenya using a retrospective cohort study design. McKelvey (2010) uses cross-sectional household data from 13 other countries in Sub-Saharan Africa to analyse the effect of circumcision on HIV status and HIV status on employment status. Levinsohn et al. (2013) use a propensity score matching approach to examine the impact of HIV/AIDS on employment in South Africa, a middle-income country. At the macroeconomic level, male circumcision has been used as an instrument to evaluate the impact of HIV/AIDS on economic growth and savings in African nations (Ahuja et al., 2009), the skill premium in Sub-Saharan Africa (Marinescu, 2014) and the impact of self-reported HIV status on employment status across countries (McKelvey, 2010). Few studies explore the pathway through which this effect occurs. Thirumurthy et al. (2013) analyse the impact of severity of disease using data from Kakyere parish in Mbarara District, Uganda, and find that higher CD4 count is associated with more days worked over the course of a past month. We build upon this by using national data.

This paper estimates a causal effect of HIV status on employment, which is achieved by using an instrumental variable in a recursive bivariate probit model using recent, publically available household survey data from Uganda. We use data from the 2011 Uganda AIDS Indicator Survey, the only Demographic and Health Survey to collect CD4 cell count in addition to biometric HIV status. The instrument, male circumcision has been shown in the medical literature to substantially decrease the probability of HIV infection. In 2007, clinical evidence from three major trials undertaken in South Africa, Kenya and Uganda showed the efficacy of male circumcision in protecting against HIV infection to be a risk reduction of 60% (Avert et al., 2005; Bailey et al., 2007; Gray et al., 2007). The IV strategy overcomes simultaneity bias arising from the effect that employment status has on the likelihood of becoming HIV infected, and, unlike the control function and propensity score matching approach applied by Levinsohn et al. (2013), this approach does not rely on selection on observables (Jones, 2017). Unlike McKelvey (2010), who considers 13 countries, we focus on Uganda, using data from the 2011 Uganda AIDS Indicator Survey (UAIS). The pathway through which HIV

might affect employment is explored by assessing the association between different levels of HIV illness (as measured by CD4 cell count) and employment outcomes. We further address the question of whether the effect occurs on the supply or demand side by evaluating the effect by employment sector and for agricultural manual laborers only.

Over 90%, the majority of Uganda's labor force is informally employed and more than half of individuals are self-employed. Most (66% of males and 77% of females) work in agriculture, forestry and fishing, almost a quarter (24% of males and 19% of females) are employed in service, and the remainder are employed in manufacturing (Uganda Bureau of Statistics, 2013). Uganda is broadly representative of low-income countries in the region, with a labor force participation rate of 78% (compared to the region average of 76%) and an ART coverage rate of 57% (compared to the region average of 51%) (World Bank, 2017a). The prevalence of HIV within low-income countries in Sub-Saharan Africa ranges from less than 1% in Madagascar to 15% in Zimbabwe, and is 7% in Uganda (World Bank, 2017b). The Ugandan government has made employment a central focus in its plans to continue to grow the economy, and as agriculture is the primary employment sector, the government has committed to improving productivity in that sector (Safavian et al., 2017). An estimate of the effect of HIV on employment can help guide policy makers making decisions around where to target resources to achieve this aim.

## 2. Data and sample

### 2.1. Data

The data used for empirical analysis were collected in 2011 in Uganda via the 2011 UAIS, a nationally representative dataset that contains biometric HIV data in addition to information on employment status. Interviews and HIV tests were conducted by trained interviewers among all men and women aged 15–59 in each of 11,750 randomly selected households.

The binary outcome variable employment status is 'currently employed.' 'Currently employed' is defined as having done work in the past seven days and includes individuals who are regularly employed and were absent from work for leave, illness, vacation, or any other such reason in the past seven days.<sup>2</sup> This matches the International Labor Organization's definition of employment, which includes all individuals in a specified age group who were engaged either in paid employment or self-employment over the period of a week (or day, whichever is specified) (World Bank, 2015). Individuals who respond that they have not been in employment over the last week may therefore be unemployed or have withdrawn from the labor market.

The treatment variable is HIV status. Data on this was collected biometrically via a rapid test during the survey, and the results were later confirmed in laboratory. The HIV test uptake rate was 96% (1% of interviewed respondents refused the HIV test and 3% were not interviewed). CD4 cell count tests were done in the central laboratory for individuals who tested HIV-positive.<sup>3</sup> Population based surveys are considered the gold standard for

<sup>2</sup> This variable is a combination of two responses from the survey: "Have you done any work in the last seven days?" and "Although you did not work in the last seven days, do you have any job or business from which you were absent for leave, illness, vacation or any other such reason?" Individuals were coded as 1 they answered "yes" to either of the questions and 0 otherwise.

<sup>3</sup> CD4 results are available for 81% of males in the sample. The shortfall is largely made up of individuals who tested HIV-negative on the home-based rapid test and HIV-positive in the central laboratory, although some may be due to logistical problems such as samples reaching the central laboratory too late to be tested for CD4 (Uganda Ministry of Health, 2012).

determining HIV prevalence (Mishra et al., 2006; Janssens et al., 2014), and biometric HIV data is important as Fishel et al. (2014) find that substantial underreporting of positive HIV status exists among respondents who are likely to know they have HIV. In general, across the Demographic and Health Surveys, HIV testing coverage rates have improved over time and vary between countries (e.g., with Rwanda also having very high HIV testing coverage rates). The Ugandan HIV prevalence estimates are based upon the UAIS, indicating its veracity (Uganda AIDS Commission, 2015).

The dataset includes information on whether a male is circumcised or not for all males in the sample, as well as information on each respondent's age at circumcision, whether they were circumcised at a health care facility, at home, at a mosque or religious provider or elsewhere. Among intact (not circumcised) males, the dataset includes information on whether they would like to be circumcised. The survey also includes variables that may affect both employment and HIV status. There is also data on occupation and sector, however; only for those individuals who reported working in the last year. Men in the sample reported working in 100 distinct jobs. These occupations are categorized into four sectors: non-manual labor, agricultural manual labor, skilled manual labor and unskilled manual labor.

## 2.2. Sample

This study focuses on men aged 25–59. The response rate among men was 96% resulting in data for 9588 men between the ages of 15 and 59. Although the 15–44 year old age group is more commonly given in reports by UNAIDS and WHO as the working age population (see, for example, Global Report: UNAIDS report on the global AIDS epidemic, 2013; Global Update on the Health Sector Response to HIV, 2014), we exclude 15–24 year olds to ensure that the sample captures those in the labor market and not enrolled in education. In addition, analysis has been restricted to non-Muslim men, as Muslim men (who make up 13% of males) have higher rates of circumcision (99%) and may also be subject to unobservable factors like discrimination that may affect employment.

## 3. Econometric methodology, instrumental variable and empirical strategy

An instrumental variable (IV) approach is used to estimate a joint model of HIV status and employment status, which overcomes endogeneity arising from simultaneity bias, with exclusion restrictions imposed upon the chosen instrument. This does not rely upon selection on observables and can be estimated by full information maximum likelihood estimation, which can take account of binary health and employment variables (Jones, 2017). A probit model was chosen over a linear model as in inherently nonlinear settings involving endogeneity 2SLS can result in substantial bias (Terza et al., 2008) and bivariate probit estimators are more robust to non-normality than linear IV (Bhattacharya et al., 2006).

Biometrically measured HIV status is used (as opposed to self-reported HIV status, which also exists in the data) to overcome the potential for overestimating the impact on employment due to justification bias.

### 3.1. Univariate probit

In order to illustrate the magnitude of bias present when HIV status is assumed to be independent of employment a univariate probit is estimated. Employment is empirically observed as a binary variable  $y_i$  that takes the value one if the individual is in

employment and zero otherwise. Eq. (1) assumes that  $y_i$  is determined by a latent variable  $y_i^*$ , where  $y_i = 0$  if  $y_i^* \leq 0$  and  $y_i = 1$  if  $y_i^* > 0$  and that  $y_i^*$  is a linear function of HIV status ( $B_i^{HIV}$ ) and other variables ( $x_i$ ):

$$y_i^* = \delta B_i^{HIV} + x_i' \beta_1 + \varepsilon_i \quad (1)$$

where  $i$  indexes individuals;  $B_i^{HIV}$  is a binary variable taking the value one if the individual has HIV and zero otherwise;  $x_i$  is a vector of covariates. Assuming these are all exogenous variables, then a univariate probit model can be used to evaluate the causal impact of HIV status on employment status.  $\varepsilon_i$  is the error term, which is assumed to be normally distributed.

Given the likelihood of endogeneity arising from employment status affecting HIV status, the resulting average treatment effect (ATE), average treatment effect on the treated (ATT) and average treatment effect on the not treated (ATNT) from (1) could be biased.

### 3.2. Recursive bivariate probit

Due to the binary nature of the treatment and outcome variables, the likelihood of endogeneity arising from employment status affecting HIV status and the potential correlation between unobservable characteristics affecting health and employment in the health and employment equations, a recursive bivariate probit using an instrumental variable is employed.<sup>4</sup> In our context, the recursive bivariate probit model takes the following form:

$$\begin{aligned} y_i^* &= x_i' \beta_2 + \gamma B_i^{HIV} + \lambda_i \\ B_i^{HIV*} &= x_i' \beta_3 + \alpha Z_i + \mu_i \end{aligned} \quad (2)$$

where  $y_i^*$  is a latent variable underlying an individual's employment status;  $B_i^{HIV}$  is an individual's HIV status;  $x_i$  is the same vector of controls presented in (1);  $B_i^{HIV*}$  is a latent variable determining  $B_i^{HIV}$  where  $B_i^{HIV} = 0$  if  $B_i^{HIV*} \leq 0$  and  $B_i^{HIV} = 1$  if  $B_i^{HIV*} > 0$ ;  $Z_i$  is a binary variable for male circumcision (the instrument);  $\lambda_i$  is the error term of the first equation and  $\mu_i$  is the error term of the second equation, which are assumed to follow a bivariate Normal distribution with correlation coefficient  $\rho$ . The second equation predicts HIV status using an instrumental variable  $Z_i$ , male circumcision, in order to get around the endogeneity present in Eq. (1). For comparison we also estimate this model using 2SLS.

### 3.3. Calculating treatment effects

The ATT is computed using the partial effect on the conditional probability for only the  $n_{B^{HIV}}$  individuals that are HIV positive (Chiburis et al., 2011), such that:

$$\Delta_{ATT} = E[Y_1|B = 1] - E[Y_0|B = 1] \quad (3)$$

$$\Delta_{ATT} = \frac{1}{n_{B^{HIV}}} \sum_{i=1}^{n_{B^{HIV}}} \frac{\Phi_2(x_i' \beta_2 + \gamma, x_i' \beta_3 + \alpha Z_i, \rho) - \Phi_2(x_i' \beta_2, x_i' \beta_3 + \alpha Z_i, \rho)}{\Phi(x_i' \beta_2)} \quad (4)$$

The average treatment effect for the  $(n - n_{B^{HIV}})$  HIV negative individuals (ATNT) is given by:

$$\Delta_{ATNT} = E[Y_1|B = 0] - E[Y_0|B = 0] \quad (5)$$

<sup>4</sup> While a bivariate probit estimator is preferable in our context, we also estimate a 2SLS model for comparison. See Appendix A for the 2SLS results.

It can be computed by:

$$\Delta_{ATNT} = \frac{1}{n - n_{B^{HIV}}} \sum_{i=1}^{(n - n_{B^{HIV}})} \frac{\Phi_2(x_i' \beta_2 + \gamma, -(x_i' \beta_3 + \alpha Z_i), \rho) - \Phi_2(x_i' \beta_2, -(x_i' \beta_3 + \alpha Z_i), \rho)}{1 - \Phi(x_i' \beta_2)} \quad (6)$$

The ATE is given by:

$$\Delta_{ATE} = E[Y_1] - E[Y_0] \quad (7)$$

It can be computed by taking the proportion of HIV negative individuals in the sample multiplied by the ATNT and adding that to the proportion of HIV positive individuals in the sample multiplies by the ATT, such that:

$$\Delta_{ATE} = \frac{n_{B^{HIV}}}{n} \Delta_{ATT} + \frac{n - n_{B^{HIV}}}{n} \Delta_{ATNT} \quad (8)$$

Where observable characteristics that affect employment differ between HIV positive and HIV negative individuals, in a non-linear model the treatment effects for treated individuals may differ from the average treatment effect for the full sample. The ATT better reflects the transmission process of HIV, where newly infected individuals are more likely to be similar to the treatment group (i.e., those already HIV positive) in the analysis, rather than a random draw from the population.

### 3.4. The instrumental variable

The instrument, male circumcision, has precedent within the literature and has been used by [Marinescu \(2014\)](#), who finds there to be no correlation between male circumcision and major determinants of wages and human capital and [Ahuja et al. \(2009\)](#) who show that neither country-level income or life expectancy are related to male circumcision rate. It also forms a component of the instrument used by [McKelvey \(2010\)](#).

In 2007, the WHO began to recommend male circumcision as a partial prevention against HIV infection on the back of strong evidence from randomized controlled trials ([WHO, 2007](#)). It has been argued that after this time, men who were more educated or more able to access and afford the procedure were more likely to have it performed ([McKelvey, 2010](#)). Contrary to this, recent evidence from Malawi, where individuals were randomized to receive or not receive information about the preventative effects of circumcision against HIV, found no evidence that individuals or parents of individuals altered their behavior on the back of this information ([Godlonton et al., 2016](#)). To test this in our sample, sensitivity analyses where first all men circumcised as adults and second all men circumcised after 2006 were eliminated from the sample are also conducted. To address the possibility that socioeconomic status is correlated with both circumcision and employment, circumcision was regressed against wealth and the vector of controls, and the coefficient was not found to be significant ( $p = 0.192$ ). Additionally, in a 2010 cross-sectional study on awareness of male circumcision for HIV prevention in Uganda, [Wilcken et al. \(2010\)](#) found that although youth are concerned with the cost and accessibility of circumcision services, adults, who are the primary decision-makers around the circumcision of their younger male family members, were not.

### 3.5. Control variables

Variables that may affect both employment and HIV status are controlled for. Following [Morris \(2007\)](#), we grouped these into four categories: labor market factors, education, home life and

additional controls as set out in the empirical framework. Labor market factors include non-employment rates by ethnicity and Uganda Bureau of Statistics (UBOS) region, and the interaction between the two. Non-employment rate by ethnicity was constructed using the present dataset and sample to reflect the different average labor market activity of ethnicities. Non-employment rate by region was taken from Uganda Bureau of Statistics data ([Uganda Bureau of Statistics, 2014](#)). Continuous variables were preferred over dummies for each region/ethnicity in the interest of preserving degrees of freedom. Month of interview is also included as more than one third of the sample is engaged in subsistence agriculture, highly seasonal work that is likely to be a strong determinant of current employment. Education is measured by dummies indicating whether an individual has completed primary, secondary, higher or no education. Home life factors that influence work and HIV status are measured by dummies for marital status and gender of an individual's head of household and the age and of the individual's head of household and a dummy variable indicating whether there are children under-5 in the household. Additional controls include dummies for 5-year age categories, religion (Christian or other, of which only 1% fall into the latter category), and a dummy variable for living in a rural area.

### 3.6. Sub-analyses on employment sector

Whether the effect of HIV on employment status differs depending upon which sector an individual is employed in is also tested. There is data on occupation for all individuals who were employed at any point in the past year at the time of survey; however there is no occupation data for the 3.3% of individuals who were not employed during the past year. As such, in order to split the sample by sector it was necessary to impute sector for those individuals. The imputation is described in [Appendix B](#).

The main model specification is replicated on each of three sub-samples using exactly the same vector of controls. These sub-samples are: non-manual laborers; manual laborers (i.e., individuals working in agricultural manual labor, skilled manual labor and unskilled manual labor); and subsistence farmers (i.e., individuals working in agricultural manual labor, which is a subset of all manual laborers). If the magnitude of the effect is larger among manual laborers, this may imply that it is the physical effects of illness (rather than, for example, stigma) that is driving the effect. However, given that the manual labor category comprises self-employed and non-self-employed occupations, it is not possible to tell from this alone whether the effect is supply side (i.e., driven by the physical effects of illness) or demand side (i.e., driven by, for example, employers not hiring HIV-positive individuals due to stigma). The model is run on a sub-sample of only individuals in the agricultural manual labor category in an effort to identify the labor supply side effect.<sup>5</sup>

### 3.7. Evaluating the association between different levels of HIV illness and employment

In an effort to illuminate the pathway through which HIV might affect employment status we consider the relationship between different levels of CD4 cell count and employment among HIV-positive individuals. Male circumcision affects HIV status, but has no effect on the trajectory of illness once infected. In the absence of a suitable instrumental variable a probit is used to estimate the

<sup>5</sup> As imputation was done at the occupation category level it is not possible to completely limit the sample only to individuals in subsistence agriculture or animal rearing; however, more than 90% of individuals in this category work in subsistence agriculture or animal rearing.

**Table 1**  
Employment by individual characteristics.

	Non-employed		Employed	
	Mean	Standard Deviation	Mean	Standard Deviation
HIV result (1 = positive, 0 = negative)	9.16%	0.29	8.36%	0.28
Circumcision status (1 = circumcised, 0 = uncircumcised)	9.12%	0.29	17.85%	0.38
<b>Labor market factors</b>				
Month of interview				
February	10.88%	0.31	5.61%	0.23
March	18.95%	0.39	14.13%	0.35
April	8.77%	0.28	12.92%	0.34
May	20.35%	0.40	19.94%	0.40
June	14.04%	0.35	16.60%	0.37
July	6.67%	0.25	12.92%	0.34
August	20.00%	0.40	17.67%	0.38
September	0.35%	0.06	0.22%	0.05
<b>Education</b>				
Education				
None	19.30%	0.40	8.19%	0.27
Primary	51.23%	0.50	58.52%	0.49
Secondary	18.95%	0.39	23.36%	0.42
Higher	10.53%	0.31	9.94%	0.30
<b>Home life</b>				
Age of household head	41.74	12.79	39.71	11.01
Gender of household head (0 = female, 1 = male)	83.51%	0.37	91.89%	0.27
Children under 5 in household (1 = yes, 0 = no)	64.21%	0.48	66.55%	0.47
Married (1 = yes, 0 = no)	62.81%	0.48	74.24%	0.44
<b>Other</b>				
Religion				
Christian	98.25%	0.13	99.01%	0.10
Other	1.75%	0.13	0.99%	0.10
Rural (1 = yes, 0 = no)	83.16%	0.37	83.76%	0.37
5-year age category				
25–29	24.21%	0.43	21.41%	0.41
30–34	16.49%	0.37	18.94%	0.39
35–39	14.74%	0.36	18.43%	0.39
40–44	14.39%	0.35	14.75%	0.35
45–49	9.82%	0.30	12.68%	0.33
50–54	10.53%	0.31	8.41%	0.28
55–59	9.82%	0.30	5.39%	0.23
Wealth quintile				
1	38.60%	0.49	20.77%	0.41
2	20.70%	0.41	20.65%	0.40
3	11.58%	0.32	19.12%	0.39
4	14.04%	0.35	17.91%	0.38
5	15.09%	0.36	21.55%	0.41
DHS ethnic category				
Baganda	9.82%	0.30	14.84%	0.36
Banyankore	2.81%	0.17	9.37%	0.29
Iteso	15.79%	0.37	9.01%	0.29
Lugbara/Madi	10.53%	0.31	7.04%	0.26
Basoga	1.75%	0.13	6.96%	0.25
Langi	3.51%	0.18	8.08%	0.27
Bakiga	2.46%	0.16	5.35%	0.23
Karimojong	14.74%	0.36	1.63%	0.13
Acholi	12.63%	0.33	4.76%	0.21
Bagisu/Sabiny	3.51%	0.18	6.76%	0.25
Alur/Jopadhola	4.56%	0.21	6.41%	0.24
Banyoro	2.81%	0.17	3.70%	0.19
Batoro	2.46%	0.16	2.59%	0.16
Other	12.63%	0.33	13.49%	0.34
UBOS region				
Northern	58.60%	0.49	30.81%	0.46
Western	7.02%	0.26	21.43%	0.41
Central	15.79%	0.37	19.42%	0.40
Eastern	8.77%	0.28	19.86%	0.40
Kampala	9.82%	0.30	8.49%	0.28

Sample: Non-Muslim males aged 25–59.

**Table 2**  
Univariate probit regression for employment probability.

	Employment coefficient	Robust standard error	Marginal effect	Standard error
HIV status (1 = positive, 0 = negative)	−0.13	0.11	−0.01	0.01
<b>Labor market factors</b>				
Non-employment rate by ethnicity	−7.11***	0.97	−0.65***	0.09
Non-employment rate by UBOS region	−7.63***	2.12	−0.70***	0.19
Interaction between unemployment rates	36.38*	18.92	3.32*	1.73
Month of interview				
February				
March	0.27***	0.13	0.02**	0.01
April	0.72***	0.15	0.07***	0.01
May	0.50***	0.13	0.05***	0.01
June	0.47***	0.13	0.04***	0.01
July	0.79***	0.16	0.07***	0.01
August	0.22*	0.12	0.02*	0.01
September	0.37	0.68	0.03	0.06
<b>Education</b>				
Education				
None				
Primary	0.20*	0.10	0.02*	0.01
Secondary	0.28**	0.12	0.03**	0.01
Higher	0.12	0.13	0.01	0.01
<b>Home life</b>				
Age of household head	0.00	0.00	0.00	0.00
Gender of household head (1 = male, 0 = female)	0.28***	0.10	0.03***	0.01
Children under 5 in household (1 = yes, 0 = no)	−0.09	0.07	−0.01	0.01
Married (1 = yes, 0 = no)	0.31***	0.07	0.03***	0.01
<b>Other</b>				
Religion				
Christian				
Other	0.05	0.33	0.00	0.03
Rural (1 = yes, 0 = no)	−0.15	0.14	−0.01	0.01
5-year age category				
25–29				
30–34	0.08	0.10	0.01	0.01
35–39	0.15	0.10	0.01	0.01
40–44	0.04	0.11	0.00	0.01
45–49	0.12	0.12	0.01	0.01
50–54	−0.16	0.12	−0.01	0.01
55–59	−0.38***	0.14	−0.03***	0.01
Constant	1.60***	0.31		
N		5206		
Log pseudolikelihood		−911.08***		
Wald chi2(26)		290.97		
McFadden's pseudo R-squared		0.15		

Reference category for education is no education; age category is 25–29; religion is Christian; and month of interview is February. Significance levels: \*10%, \*\*5%, \*\*\*1%.

association between different levels of CD4 cell count and employment:

$$y_i^* = \beta_1 x_i + \gamma B_i^{CD4} + \eta_i \tag{9}$$

where  $y_i^*$  is again a latent variable underlying an individual's employment status;  $B_i^{CD4}$  is a dummy variable indicating whether an individual's CD4 cell count is above or below a certain threshold;  $x_i$  is the same vector of controls presented in (1); and  $\eta_i$  is the error term, which is normally distributed. Thresholds of 200, 250, 300, 350, 400, 450 and 500 cells/mm<sup>3</sup> are used.<sup>6</sup> If indeed there is a supply side effect, we might expect the magnitude of the

effect to be greater for individuals with lower CD4 cell counts compared to higher ones as CD4 cell counts reflect the progression of disease and worsening morbidity.

#### 4. Results

##### 4.1. Descriptive statistics

Summary statistics are given in Table 1. There appears to be little difference in HIV prevalence between non-employed and employed individuals. However, this may be driven by observable or unobservable characteristics between HIV-positive and HIV-negative individuals. Female headed households are more common among non-employed individuals than employed individuals, as well as being in a lower wealth quintile.

##### 4.2. The impact of HIV on employment: assuming exogeneity

Table 2 presents the results of a univariate probit where HIV status is assumed to be exogenous to employment. The marginal

<sup>6</sup> While WHO recommended treating all HIV-infected individuals in 2015, at the time of this survey the 2009 guidance recommended treating individuals with CD4 cell counts of 350 cells/mm<sup>3</sup> or lower (World Health Organization, 2010). In Uganda, all patients with CD4 cell counts of 200 cells/mm<sup>3</sup> were initiated on ART. For individuals with CD4 cell counts between 200 cells/mm<sup>3</sup> and 350 cells/mm<sup>3</sup> the decision whether or not to initiate ART was based on a clinical assessment of presence of symptoms in line with WHO HIV stages (Katabira et al., 2008).

**Table 3**  
Recursive bivariate probit estimation.

	coefficient	standard error	ATE	ATT
<i>Impact of HIV status on employment</i>				
HIV status (1 = positive, 0 = negative)	−0.96**	(−0.46)	−0.14	−0.05
<i>Impact of instrument on HIV status</i>				
Circumcision status (1 = circumcised, 0 = uncircumcised)	−0.21***	(−0.07)		

Significance levels: \*10%, \*\*5%, \*\*\*1%. Observations: 5206. Disturbance correlation: 0.39 Chi2 (1): 3.5594\*.

Sample: Non-Muslim males aged 25–59.

Standard errors are clustered at the household level.

effect of being HIV positive on employment status is  $-0.01$ , which can be interpreted as showing that being HIV positive is associated with a 1% reduction in the likelihood of being employed. This reduction is, however, not statistically significant. This model does not account for possible endogeneity, on which there is more in Section 4.3, and so coefficients should only be used for comparison. However, the statistically significant coefficients are broadly in line with a priori intuition; for example, months of interview beside the baseline category of February and the month of September mostly show a significant positive effect on employment, in line with expectations given that harvesting did not take place during these months in 2011 (Famine Early Warning Systems Network, 2011, 2010).<sup>7</sup>

#### 4.3. The impact of HIV on employment status: controlling for endogeneity

The ATE and ATT from results of the recursive bivariate probit are given in Table 3, calculated from the joint and marginal distributions, while Table 4 presents all coefficients from both parts of the simultaneously estimated equation and their marginal effects, calculated from the marginal distributions. Table 5 provides the results of a 2SLS model for comparative purposes.<sup>8</sup>

As shown in Table 3, the correlation coefficient of the disturbances  $\rho(\varepsilon, \eta)$  is positive and significant at the 10% level according to the Wald ratio test. Thus, HIV is endogenous for males and the bivariate probit is the appropriate model.<sup>9</sup> The positive sign of the correlation coefficient implies that the effect of HIV on employment is underestimated by the univariate probit. The ATT is  $-0.05$ , which indicates a 5 percentage point reduction in the likelihood of employment for HIV-positive males. The ATE is  $-0.14$  from this model is significant compared to a marginal effect of 1 percentage point from the univariate probit, which was not statistically significant. This difference in magnitude and significance likely arises from an unobserved selection process into HIV status that causes this bias. Two potential sources are either that employment increases the likelihood of having HIV or that HIV is positively (negatively) correlated with unobservables that are themselves positively (negatively) associated with employment status. These are known as reverse causality/simultaneity bias and omitted variable bias, respectively. An example of reverse causality may be more access to sex markets where HIV can be transmitted resulting from employment while an example of an unobservable variable may be risk preference, which may be correlated with

both HIV and employment, but, we argue, not with circumcision status after having controlled for a number of other variables. The exogenous variation in HIV status caused by male circumcision provides an appropriate identification strategy for the causal effect that should control for the endogeneity and therefore provide an unbiased estimate.

The marginal effects of the coefficients in each equation are presented in Table 4. As expected, the instrument, male circumcision, reduces the likelihood of having HIV, and the predicted 3 percentage point reduction is statistically significant. Being married and having children under-5 in the household are associated with a 5 and 3 percentage point reduction in the likelihood of being HIV positive respectively.<sup>10</sup> Reductions in the likelihood of employment result from non-employment rates by region and ethnicity reflecting the effect of macroeconomic conditions on individuals' employment status. Just as in the univariate model where exogeneity of being HIV-positive is assumed, individuals interviewed from March to August are 3–8 percentage points more likely to be employed compared to those interviewed in February, which is not a harvest month in Uganda. These month dummies are statistically significant and follow the typical patterns in agricultural activity known to exist in Uganda (Famine Early Warning Systems Network 2011, 2010). Individuals in the sample with primary or secondary education were also more likely by 1–3 percentage points to be employed than those with no education.<sup>11</sup> Being married and having a male head of household were also predictors of employment (both by 3 percentage points). Being in the oldest age category of individuals included in the analysis (i.e., 55–59) statistically significantly decreased the likelihood of being employed by five percentage points compared with being in the youngest age category (25–29 years of age). Nearly 10% of individuals in this age category are not employed (compared to between 4 and 7% in the other categories), and among non-employed individuals in this age category 41% reported being unable to work due to a handicap and 29% reported being retired.

The results of the 2SLS model shown in full in Table 5 are presented for comparison and are generally consistent with the recursive bivariate probit analysis. Specifically, the key results are qualitatively consistent between specifications, in the 2SLS model, being HIV-positive is found to be endogenous ( $p = 0.036$ )<sup>12</sup> and has a negative significant effect on employment ( $p = 0.083$ ). The magnitude of the effect is much larger compared with the recursive bivariate probit analysis, which is preferred for reasons

<sup>7</sup> The exception is September, which is also a month associated with land preparation and sowing.

<sup>8</sup> The results without controlling for covariates are presented in Appendix A.

<sup>9</sup> The F-statistic—the standard criteria for judging the relevance of an instrument for a 2SLS regression—is obtained by running a linear regression of the first stage of the bivariate probit model. According to Stock and Yogo (2005), the F statistic of 9.29 obtained limits the bias of the model to between 10 and 15% of an ordinary least squares model, the cut-offs for which are 16.38 and 8.96 respectively for a linear model with a single instrument and single endogenous regressor (Stock and Yogo, 2005).

<sup>10</sup> The magnitude and significance of the marginal effect of being interviewed in September on the likelihood of being HIV-positive reflects that all of the small sample of individuals interviewed in September (12) were HIV negative.

<sup>11</sup> While 94% of individuals who had completed higher education were employed (compared to 96% who had completed secondary, 95% who had completed primary and 89% with no education), there were fewer individuals in the sample that had completed higher education and having done so compared to having no education was not a significant predictor of employment.

<sup>12</sup> The corresponding result from the recursive bivariate probit model here is the observed statistical significance of the rho coefficient.

**Table 4**  
Recursive bivariate probit estimation, full results.

	Employ-ment coefficient	Robust standard error	Marginal effect	Standard error	HIV coefficient	Robust standard error	Marginal effect	Standard error
HIV status (1 = positive, 0 = negative)	-0.96**	0.46	-0.10*	0.05				
Circumcision status (1 = circumcised, 0 = uncircumcised)					-0.21***	0.07	-0.03***	0.01
<b>Labor market factors</b>								
Non-employment rate by ethnicity	-7.03***	0.96	-0.70***	0.10	-0.56	0.97	-0.08	0.14
Non-employment rate by UBOS region	-7.55***	2.08	-0.75***	0.21	-0.35	1.49	-0.05	0.22
Interaction between unemployment rates	36.05*	18.73	3.59*	1.87	4.78	18.38	0.70	2.69
Month of interview								
February								
March	0.28**	0.13	0.03**	0.01	0.15	0.13	0.02	0.02
April	0.71***	0.15	0.07***	0.02	0.06	0.13	0.01	0.02
May	0.50***	0.13	0.05***	0.01	0.09	0.13	0.01	0.02
June	0.47***	0.13	0.05***	0.01	0.13	0.13	0.02	0.02
July	0.78***	0.16	0.08***	0.02	0.14	0.13	0.02	0.02
August	0.22*	0.12	0.02*	0.01	-0.04	0.13	-0.01	0.02
September	0.31	0.67	0.03	0.07	-4.67***	0.22	-0.68***	0.04
<b>Education</b>								
Education								
None								
Primary	0.21**	0.10	0.02**	0.01	0.16	0.10	0.02	0.01
Secondary	0.28**	0.12	0.03**	0.01	0.10	0.11	0.01	0.02
Higher	0.09	0.13	0.01	0.01	-0.23*	0.14	-0.03*	0.02
<b>Home life</b>								
Age of household head	0.00	0.00	0.00	0.00	0.00*	0.00	0.00*	0.00
Gender of household head (1 = male, 0 = female)	0.26***	0.10	0.03***	0.01	-0.10	0.09	-0.01	0.01
Children under 5 in household (1 = yes, 0 = no)	-0.11	0.07	-0.01	0.01	-0.22***	0.06	-0.03***	0.01
Married (1 = yes, 0 = no)	0.28***	0.07	0.03***	0.01	-0.32***	0.06	-0.05***	0.01
<b>Other</b>								
Religion								
Christian								
Other	0.02	0.14	0.00	0.03	-0.47	0.33	-0.07	0.05
Rural (1 = yes, 0 = no)	-0.17	0.14	-0.02	0.01	-0.20**	0.09	-0.03**	0.01
5-year age category								
25–29								
30–34	0.12	0.10	0.01	0.01	0.49***	0.09	0.07***	0.01
35–39	0.19*	0.10	0.02*	0.01	0.52***	0.09	0.08***	0.01
40–44	0.09	0.11	0.01	0.01	0.59***	0.10	0.09***	0.01
45–49	0.16	0.12	0.02	0.01	0.49***	0.11	0.07***	0.02
50–54	-0.14	0.12	-0.01	0.01	0.25**	0.13	0.04*	0.02
55–59	-0.38***	0.14	-0.04***	0.01	0.02	0.15	0.00	0.02
Constant	1.65***	0.31			-1.46***	0.26		
N	5206							
Log pseudolikelihood	-2327.75							
Wald chi2(2; 52)	1842.35***							
$\rho(\varepsilon, \eta)$ (disturbance correlation)	0.39*							

Reference category for education is no education; age category is 25–29; religion is Christian; and month of interview is February. Standard errors are clustered at the household level.

Significance levels: \*10%, \*\*5%, \*\*\*1%.

outlined in the methodology, and this illustrates that the difference between the two econometric estimation methods are not only conceptual but also result in substantial different estimates of the impact of being HIV-positive in employment.

#### 4.4. The impact of HIV on employment status: sensitivity analyses

Additional sensitivity analyses are undertaken to demonstrate the robustness of the instrument, and these results are reported in Table 6.

First, all men circumcised as adults and all men circumcised after 2006 were eliminated from the sample. Both the instrument

and the coefficient for HIV remained significant. The magnitude of the ATT did not change, while the magnitude of the ATE increased about 3 percentage points (to 17 percentage points). The change in the ATE is due to changes in the coefficients that were estimated when the sample was limited to only men circumcised in 2006 or earlier. When the ATE for this subsample of the population was estimated using the betas from the original population the resulting ATE was the same as the original model at -0.14. An additional check was conducted whereby all men who were circumcised as adults, defined as age 15 or older, were excluded from the sample. Once again, both the instrument and the coefficient for HIV remained significant in the recursive bivariate

**Table 5**  
2SLS estimation for non-Muslim males aged 25–59, full results.

	Employment coefficient	Robust standard error	HIV coefficient	Robust standard error
HIV status (1 = positive, 0 = negative)	–0.47*	0.27		
Circumcision status (1 = circumcised, 0 = uncircumcised)			–0.03***	0.01
<b>Labor market factors</b>				
Non-employment rate by ethnicity	–1.14***	0.25	–0.07	0.14
Non-employment rate by UBOS region	–0.57***	0.26	–0.06	0.24
Interaction between unemployment rates	3.67	5.26	0.50	2.78
Month of interview				
February	0.04**	0.02		
March	0.07***	0.02	0.02	0.02
April	0.06***	0.02	0.01	0.02
May	0.06***	0.02	0.01	0.02
June	0.08***	0.02	0.02	0.02
July	0.03***	0.02	0.02	0.02
August	0.00	0.09	–0.01	0.02
September	0.00	0.00	–0.07***	0.02
<b>Education</b>				
Education				
None				
Primary	0.04**	0.02	0.02	0.01
Secondary	0.04**	0.02	0.01	0.02
Higher	0.01	0.02	–0.03**	0.02
<b>Home life</b>				
Age of household head	0.00	0.00	0.00	0.00
Gender of household head (1 = male, 0 = female)	0.03	0.02	–0.02	0.02
Children under 5 in household (1 = yes, 0 = no)	–0.02*	0.01	–0.03***	0.01
Married (1 = yes, 0 = no)	0.00	0.02	–0.05***	0.01
<b>Other</b>				
Religion				
Christian				
Other	–0.01	0.05	–0.05*	0.03
Rural (1 = yes, 0 = no)	–0.02	0.02	–0.03**	0.02
5-year age category				
25–29				
30–34	0.03*	0.02	0.06***	0.01
35–39	0.04**	0.02	0.06***	0.01
40–44	0.04*	0.02	0.08***	0.01
45–49	0.04*	0.02	0.06***	0.02
50–54	0.00	0.02	0.02	0.02
55–59	–0.04*	0.02	–0.01	0.02
Constant	0.96	0.09	0.10***	0.0391
N	5206			
First stage F-statistic on excluded instrument	9.29***			
Wald chi2(1; 26)	167.93***			

Reference category for education is no education; age category is 25–29; religion is Christian; and month of interview is February. Significance levels: \*10%, \*\*5%, \*\*\*1%.

**Table 6**  
Recursive bivariate probit sensitivity analyses

Impact of HIV status on employment	n	coefficient	Robust standard error	ATE	ATT
(1) Eliminating all men circumcised after 2006	5152	–1.12**	0.48	–0.17	–0.05
(2) Eliminating all men circumcised after age 15	4672	–1.09**	0.48	–0.17	–0.06
(3) Including Muslims	5980	–1.14**	0.45	0.18	–0.05
Impact of instrument on HIV status		coefficient	standard error	$\rho(\varepsilon, \eta)$	$\chi^2$
(1) Eliminating all men circumcised after 2006		–0.22***	0.08	0.47	4.73**
(2) Eliminating all men circumcised after age 15		–0.24**	0.11	0.46	4.30**
(3) Including Muslims		–0.22***	0.07	0.47	5.43**

Significance levels: \*10%, \*\*5%, \*\*\*1%; Sample: Non-Muslim males aged 25–59 in (1) and (2), all males aged 25–59 in (3). Standard errors are clustered at the household level.

probit. The magnitude of the ATE increased while the ATT remained largely the same. As in the previous sensitivity analysis, a look into whether changes in the coefficients estimated for the control variables were responsible for the change in the ATE showed that this was again the case.

While there is a valid theoretical argument for eliminating Muslims from the sample given that they have high rates of male circumcision and may also be subject to unobservable factors that may affect employment, a sensitivity analysis was carried out to ensure that this did not adversely affect the results. Indeed, the

**Table 7**  
Recursive bivariate probit by occupation category.

Occupation category	n	Impact of HIV status on employment			
		coefficient	standard error	ATE	ATT
Non-manual labor	1276	0.35	0.53	0.02	0.02
Manual labor (skilled, unskilled and subsistence agricultural)	3930	−1.15**	0.47	−0.18	−0.07
Subsistence agricultural	1880	−0.32	1.38	−0.03	−0.04

  

	Impact of instrument on HIV status			
	coefficient	standard error	$\rho(\varepsilon, \eta)$	$\chi^2$
Non-manual labor	−0.34**	0.16	−0.05	0.04
Manual labor (skilled, unskilled and agricultural)	−0.16*	0.08	0.43	4.30**
Subsistence agricultural	−0.23	0.14	−0.01	0.00

Significance levels: \*10%, \*\*5%, \*\*\*1%.  
Standard errors are clustered at the household level.

coefficients remained statistically significant. The ATE increased in magnitude by 5 percentage points. Similar to the previous sensitivity analyses, changes in the coefficients estimated for the control variables explain the change in the ATE.

#### 4.5. The impact of HIV on employment status by sector

More than one in three individuals in the sample (36%) work in the agricultural manual labor sector (or would if they were employed). 30% are unskilled manual laborers, 25% are non-manual laborers and the remaining 10% are skilled manual laborers. Among HIV positive individuals in the sample, a disproportionately large share are in the skilled manual labor and unskilled manual labor sectors.

Table 7 shows the ATE and ATT when the sample is restricted to non-manual laborers and when it is restricted to manual laborers, as well as when the sample is restricted to subsistence agriculture workers only. The same vector of controls is included (as in the main model specification) for each sub-sample. Despite the small sample size, some inferences can be drawn. The ATT is large and statistically significant for manual laborers, suggesting a reduction in the likelihood of employment of 7 percentage points among this group. It is small, not significant and counterintuitive for non-manual laborers. That it is larger for manual laborers than for the overall sample (5 percentage points) suggests that the effect may be driven by physical effects of disease. However, it is also possible that a demand side effect is also at play (e.g., employers may be less likely to hire HIV-positive individuals due to stigma). In an effort to isolate a supply side effect, the manual labor sample was further limited to only individuals working in subsistence agriculture resulting in an ATT of −0.04. This is very similar to the effect found for the overall sample, providing suggestive evidence that the effect occurs primarily on the supply side, although due to the small sample size this result should be interpreted cautiously.

#### 4.6. Association between different levels of HIV illness and employment status

Table 8 shows the association between different levels of illness with HIV, as measured by CD4 cell count, and employment status at seven different CD4 cell count per mm<sup>3</sup> thresholds.

In the absence of ART, CD4 cell count declines over time. Having a CD4 cell count of 200 per mm<sup>3</sup> or below is associated with a 9 percentage point reduction in employment compared to individuals with CD4 cell counts above 200 per mm<sup>3</sup>.<sup>13</sup> In line with what

**Table 8**  
Probit estimates of the impact of CD4 count on employment for adults aged 25–59.

Cells/mm <sup>3</sup> threshold	200	250	300	350	400	450	500
Employed coefficient	−0.38**	−0.30**	−0.25**	−0.16	−0.11	−0.12	−0.05
Robust standard error	0.15	0.13	0.11	0.11	0.10	0.10	0.11
Pseudo-R-squared	0.08	0.08	0.08	0.08	0.08	0.08	0.08
ATT	−0.09	−0.07	−0.06	−0.04	−0.03	−0.03	−0.01
ATE	−0.09	−0.07	−0.06	−0.04	−0.03	−0.03	−0.01
Treated group N	118	179	251	315	410	482	551

N = 917

Sample: Non-Muslim males aged 25–59.  
Standard errors are clustered at the household level.

might be expected from a clinical perspective, this association reduces as the CD4 cell count thresholds used increase. These results further lend support to the hypothesis that there is a supply side effect.

## 5. Discussion and conclusion

We aimed to contribute to the literature by estimating the causal impact of having HIV on employment status and evaluating how that effect varies by employment sector to isolate a causal supply side effect. To overcome the endogeneity arising from simultaneity bias and omitted variable bias in the estimation of the effect of HIV on employment status, we used a recursive bivariate probit, using male circumcision as the instrument. We used biometric data on HIV status to overcome justification bias.

Without controlling for endogeneity our results suggest that being HIV positive has little effect with only a 1 percentage point reduction in the likelihood of being employed. After using male circumcision as an instrument, we find that being HIV positive causes a 5.5 percentage point reduction in the likelihood of being employed. This is smaller than the association of 13% found across 13 countries in sub-Saharan Africa (not including Uganda<sup>14</sup>) by McKelvey (2010), but similar to Levinsohn et al. (2013) who find that being HIV positive is associated with a 6–7 percentage point increase in the likelihood of being unemployed in a middle-income country, South Africa. The differences between our results and the estimate found by McKelvey (2010) may be due a number of factors, such as differences in the econometric strategies used or changes that have taken place in HIV epidemics and public health

<sup>13</sup> Because the treated group varies across the different analyses employing different cut-off points for CD4 analysis we consider ATE to allow for consistency in comparison of effects.

<sup>14</sup> Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Haiti, Kenya, Lesotho, Malawi, Rwanda, Senegal, and Tanzania

responses (e.g., availability of ART) between the 2003–5 period that McKelvey (2010) considers and the 2011 Uganda survey. The roll out of ART for treating HIV/AIDS, which has been shown to improve employment outcomes (Larson et al., 2008; Thirumurthy et al., 2008, 2011; Habyarimana et al., 2010; Rosen et al., 2010), has resulted in an increase of ART coverage among HIV positive individuals from 3% to 28% across Sub-Saharan Africa between 2005 and 2011 (World Bank, 2017a). The current analysis also extends previous work by exploring whether the effect occurs on the supply or demand side, an important factor for determining what policies might best be able to improve employment outcomes for HIV positive men, using data on employment sector and CD4 cell count, the latter of which is unique to the Uganda 2011 AIS.

The sector in which employment growth occurs has implications for economic growth and poverty alleviation (Gutierrez et al., 2007). We showed that the effect of HIV/AIDS on the likelihood of employment differs for manual and non-manual laborers, with the ATT showing a 7 percentage point reduction in the likelihood of being employed for manual laborers while the effect is not statistically significant for non-manual laborers. If, as our results suggest, manual laborers are more heavily affected, policy makers may consider targeting interventions toward that group. The sectoral analysis is also potentially useful if future research provides estimates of the net production by sector. This information can be used by policy makers in decisions around how to allocate health system resources. It may also be valuable to estimate the employment effects of HIV on females in the further research.

In an effort to disentangle supply and demand side effects, we attempted to isolate a supply side effect by limiting the sample to agricultural manual laborers, over 90% of who are self-employed in subsistence agriculture or animal rearing. The effect size was similar to that which was estimated for the original sample, suggesting that the effect may largely be a supply side one and supply side policies (e.g., increasing the availability and provision of ART) may be appropriate.

We further assessed this by evaluating the association between increased disease severity and employment status using CD4 cell count. If the supply side effect is driven by the physical effects of illness, it would be expected that as illness progresses the magnitude of the effect on employment would increase. Decreases in CD4 cell count are associated with an increased risk of co-infection with, for example tuberculosis or hepatitis, and opportunistic infections, such as certain cancers (e.g., Kaposi's sarcoma), pneumocystis pneumonia and toxoplasmosis, among others, which all result in ill health and may detriment an individual's ability to work. Even without co-infections and opportunistic infections, however, decreases in CD4 cell count lead to AIDS, which itself causes symptoms that may affect an individual's ability to work, such as fatigue, dizziness, balance issues and flu-like symptoms among others. CD4 cell count is affected by both duration of HIV-infection and treatment with ART.<sup>15</sup> The analysis of the association between different observed levels of CD4 count and employment using probit regression showed that at lower CD4 thresholds the association between having a CD4 cell count below versus above the threshold was associated with an effect on employment status of greater magnitude. Having a CD4 cell count of 200 per mm<sup>3</sup> or below (versus higher than 200) is associated with a 9 percentage point reduction in employment. Using a higher threshold of 500 per mm<sup>3</sup> the association reduces to a less than 1 percentage point reduction. This suggests that increased disease severity has a greater negative impact employment status.

While the econometric strategy used is robust, the validity of using male circumcision as an instrument may be questioned on the basis of individuals' risk preferences. For example, individuals who engage in more risky sexual behavior (and are therefore at greater risk for contracting HIV) may also be more likely to become

circumcised to lessen their risk. These same individuals might select into riskier and less steady employment. This was investigated in two different ways by first excluding males circumcised as adults and second by excluding males circumcised after 2006, when it became public knowledge that male circumcision has a preventative effect against HIV infection. The results were robust to these sensitivity analyses and consistent with the findings of Godlonton et al. (2016) who show no evidence of risk compensation related to the information that circumcision is partially preventative against HIV.

To conclude, this study aimed to estimate the causal impact of HIV status on employment. It also explored if and how that effect varies by employment sector and for agricultural manual laborers, most of who work in subsistence agriculture, to isolate a causal supply side effect. It further considered whether the association between HIV and employment varied by severity of disease, a result that could further support a supply side effect. A recursive bivariate probit, with male circumcision as the instrument, was used to overcome the endogeneity arising from simultaneity bias in the estimation of the effect of HIV on employment status. We found that being HIV positive resulted in a 5 percentage point reduction in the likelihood of being employed. The effect size differed between manual and non-manual laborers, with a 7 percentage point reduction in the likelihood of being employed for manual laborers and no evidence of a statistically significant effect for non-manual laborers. When the sample was limited to subsistence agriculture workers the effect size was very similar to what it was for the whole sample, suggesting the effect occurs largely on the supply side. Furthermore, the magnitude of the association between HIV illness (as measured by CD4 cell count) and lowered likelihood of employment was greater at lower CD4 cell counts than higher ones, suggesting that severity of disease may affect employment, particularly impairing manual laborers in undertaking their work.

### Conflict of interest

The authors have no conflicts of interest to declare.

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### Appendix A. Recursive bivariate probit and 2SLS estimation without covariates

The tables below give results where the models are estimated without additional covariates. The recursive bivariate probit estimate shows a reduction in the likelihood of employment of 78 percentage points while the 2SLS estimation shows a reduction of 106 percentage points (Table A1 and Table A2).

<sup>15</sup> In robustness checks we also considered controlling for ART, but this did not affect interpretation of results.

**Table A1**

Recursive bivariate probit estimation without covariates.

	Impact of HIV status on employment		ATE	ATT
	Employment coefficient	Robust standard error		
HIV status (1 = positive, 0 = negative)	–2.77***	0.39	–0.78	–0.06

  

	Impact of instrument on HIV status		$\rho(\varepsilon, \eta)$	$\chi^2$
	HIV coefficient	Robust standard error		
Circumcision status (1 = circumcised, 0 = uncircumcised)	–0.21***	0.07	0.96**	96.53***

Significance levels: \*10%, \*\*5%, \*\*\*1%. Observations: 5213. Disturbance correlation: 0.96 Chi2 (2): 96.53\*\*\*.

Sample: Non-Muslim males aged 25–59.

Standard errors are clustered at the household level.

**Table A2**

2SLS estimation without covariates.

	Employment coefficient	Robust standard error	HIV coefficient	Robust standard error
HIV status (1 = positive, 0 = negative)	–1.06**	0.43		
Circumcision status (1 = circumcised, 0 = uncircumcised)			–0.03***	0.01
N	5213			
First stage F-statistic on excluded instrument	8.93***			
Wald chi2(1)	6.08**			

Significance levels: \*10%, \*\*5%, \*\*\*1%.

## Appendix B. Multiple imputations

A multinomial logit model was used to impute occupation sector based on a number of socio-economic and demographic variables including ethnicity, region, household factors, level of education, religion and month of interview. Because likelihood ratio tests cannot be performed directly with multiple imputed data, a variable that was equal to the mode of the permutations of multiple imputed data by multinomial logistic regression with sequential imputation using chained equations was generated for individuals that were missing occupation. Because missing variables were relatively few, as many sequences as desired could easily be carried out. In this case, 50 datasets were created. This is well beyond the rule of thumb of 3–5.

To ensure that this technique performed well, two tests were carried out. First, the group closest in terms of employment to those who were missing occupation were tested. These were individuals who are not currently employed (and thus coded as unemployed in the data), but had been employed previously in the year leading up to the survey. For this exercise, these individuals were coded as missing. Multiple imputation by multinomial logistic regression with sequential imputation using chained equations was then carried out to generate 50 datasets. The mode was calculated for each and in 99.13% of cases it corresponded to the occupation on file for the individual. A second test was carried out whereby 6% of the sample with occupation on file was randomly chosen and coded as missing occupation. (This corresponds to the percent of the sample that is unemployed so that the imputation carried out will have a similar ratio of nonmissing data on file from which to draw.) In this scenario sector was correctly imputed 97.47% of the time. That the accuracy of imputations drawn randomly from the sample is slightly lower than that of the sample of individuals who are currently unemployed, but were employed previously in the year is sensible: The random sample was of 6% of the sample, or 319 observations, while the sample of individuals who were employed earlier in the year was smaller, representing less than 2.5% of the full sample. Given the results of these tests, we can be confident that this strategy accurately predicts the occupation category of individuals for whom this data was missing

in the sample 97–99% of the time. Of the 173 individuals in the sample (3.25%) for whom occupation category was missing, 25 (20%) were imputed as non-manual laborers, which make up 25% of the total sample; 38 (22%) were imputed as agricultural manual laborers, which make up 36% of the total sample; 2 (1%) were imputed as skilled manual laborers, which make up 10% of the total sample; and 97 (56%) were imputed as unskilled manual laborers. There was one individual for whom imputation was unsuccessful.

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